



POLLINATION

- | | | | | | | |
|----------------|----------------|-------------|-------------------|---------------|----------------|---------------|
| 1. Feijoa | 2. Posoqueria. | 3. Huernia. | 4. Hoya. | 5. Lilium. | 6. Catasetum. | 7. Stylidium. |
| 8. Coryanthes. | 9. Eucalyptus. | 10. Salvia. | 11. Scrophularia. | 12. Veronica. | 13. Parnassia. | |

**SCIENCE
IN MODERN LIFE**

SCIENCE IN · MODERN · LIFE

A SURVEY OF SCIENTIFIC DEVELOPMENT
DISCOVERY AND INVENTION AND THEIR
RELATIONS TO HUMAN PROGRESS AND
INDUSTRY

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VOLUME IV ·

THE GRESHAM PUBLISHING COMPANY

34 AND 35 · SOUTHAMPTON STREET, STRAND, LONDON

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CHAPTER III

TEMPERATE AND POLAR ZONES—DESERTS AND MOUNTAINS

TEMPERATE ZONES—CLIMATE AND SUBDIVISIONS.—The climate of the so-called temperate zones justifies the customary name only to a limited extent; for the north temperate zone, at any rate, the name of intermediate or middle would be more appropriate. The mean temperatures of the hottest and of the coldest months respectively lie far apart especially in districts with a continental climate (for instance, 50° C. [120° F.] in North-eastern Siberia), which are further characterized by extreme daily variations (amounting sometimes to 40° C. [96° F.] or more). It is convenient to recognize two SUBTROPICAL BELTS immediately adjoining the tropical zone and separating it from the temperate zones in the strict sense; either temperate zone may further be subdivided into a WARM-TEMPERATE BELT (mild-winter districts) and a COLD-TEMPERATE BELT (cold-winter districts). The subtropical belts are largely occupied by deserts, which here attain their greatest development.

WARM-TEMPERATE DISTRICTS WITH DRY WINTERS.—Those districts in the warm-temperate belt for which winter is the dry season, vary greatly as regards their vegetation, even within limited areas, in accordance with the character of rainfall and winds and other factors; but grassland and savanna-forest are perhaps commoner than pure woodland.

The wide tracts of warm-temperate savanna and steppe which formerly existed in Australia have been largely converted into excellent wheat land. In the unaltered Australian savanna the Grass Tree (*Xanthorrhoea* spp.) is a curious feature of the landscape. Savanna-forest is strikingly developed in the blue-gum districts of Australia. The giant eucalypti, 300–400 ft. high, stand, “seemingly at measured distances, singly or in small clumps, as if planted by the hands of a landscape gardener”. The undergrowth, if woody, is generally meagre, while grass maintains itself well.

WARM-TEMPERATE DISTRICTS WITH MOIST WINTERS.—The combination of mild moist winters with summer drought is found in a number

of widely separated districts, such as the Mediterranean countries, the Cape of Good Hope, South-western Australia, California, and Central Chili. Everywhere it determines a peculiar vegetation (Macchia, Scrub, Chapparal, &c.), consisting mainly of shrubs with very characteristic leathery, dull-coloured, evergreen foliage. The leaves are small and simple, often strongly aromatic, and sometimes placed vertically; the thorny shoots so common in other periodically dry districts are rare. Examples of this type of shrub are the familiar Myrtle (*Myrtus communis*), Lavender (*Lavandula vera*), and Rosemary (*Rosmarinus officinalis*) of the Mediterranean flora, the bushy Heaths (*Erica* spp.)—and heath-like plants belonging to other families—of the Cape and many of the Australian Wattles (*Acacia* spp.). The evergreen condition is no doubt connected with the almost continuous conflict between the interests of photosynthesis and of transpiration which results from the character of the climate. The hard-leaved (sclerophyllous) shrubs are accompanied by an extraordinarily rich flora of plants with bulbs, tubers, or other underground organs (geophytes), which send green shoots above ground only for a short time during the wet season.

COLD-TEMPERATE BELT.—The cold-winter belts of the temperate zones show less variety in their plant formations than any province hitherto considered, partly on account of the increased severity of the climate, and, for the rest, owing to the effects of prolonged contact with civilization. Modification by man is least marked—because of most recent origin—in North America, where forest and grassland are still on the whole distributed in accordance with the principles laid down above (vol. iii, p. 173).

FORESTS.—Cold-temperate forests are conveniently divided into two classes, namely, broad-leaved forests, composed of deciduous trees, occupying the warmer districts; and narrow-leaved or coniferous forests, inhabiting the colder tracts. The segregation implied is, however, by no means complete, and is perhaps to a great extent a consequence of human interference. In the grand forests of the Alleghanies, oaks, chestnuts, maples, beeches, birches, and the tulip-tree (*Liriodendron tulipifera*) flourish side by side with hemlock-spruce (*Tsuga canadensis*) and pines (*Pinus Strobus*, &c.); and the scanty relics of virgin forest in Europe consist of a mixture far more varied than that which composes ordinary woods. But great uniformity in composition, stature, and colouring is on the whole characteristic of cold-winter woodland, and, together with the rarity of lianes and epiphytes and the general poverty of the permanent undergrowth, gives to this formation an air of restfulness which is in sharp contrast to the activity of the tropical rain-forest.

While the evergreen (coniferous) forest is always nearly bare of undergrowth—except for the autumn crop of large fungi, which also occurs in the broad-leaved forest—the deciduous woods have a brief show of flowering undergrowth in the early spring, when light is relatively intense under the leafless crowns, besides a permanent though meagre flora of ferns, mosses and shade-loving flowering herbs such as *Oxalis Acetosella* (Woodsorrel), *Sanicula europea* (Sanicle) and *Lysimachia nemorum* (Yellow Pimpernel).

GRASSLAND.—Steppe and meadow, the two forms of cold-temperate grassland, are not clearly separable, and often occupy the same climatic region side by side, alternating in accordance with edaphic differences. On the whole, however, the steppe is more xerophilous than the meadow, and partly for this reason has not been greatly altered by man, at any rate where it occurs on a large scale; whereas natural meadows hardly exist in Western and Central Europe at the present day, and are not common in any lowland territory.

A typical steppe lacks the compact sward of the meadow, unless creeping grasses chance to be dominant, as they are in parts of the North American Prairie, where Buffalo-grass (*Buchloe dactyloides*) may exclude all other plants over large areas. In place of the rosette-perennials (such as daisy, plantain, &c.), which are almost the sole companions of the juicy, bright-green grasses in meadows, a varied assortment of geophytes, annuals, succulents and undershrubs enrich the steppe flora. Many of these, however, come above ground only for a small part of the year, and at other times the enormous expanse of bluish stiff-leaved grass, interrupted only by bare spots, forms a landscape which is decidedly monotonous, though not devoid of special charm.

DISTRIBUTION OF WOODLAND AND GRASSLAND IN COLD-TEMPERATE BELT.—In the cold-temperate belt of the northern hemisphere the natural formations consist chiefly of forest, which covers most of the land surface between the 40th and 60th parallels in America and Western Europe, and between the 50th and 60th parallels in Russia and Siberia. Steppes occupy the central portions of North America, the Hungarian Plain, Southern Russia, and the country between Lake Baikal and the Gobi, while in Manchuria and Kamchatka a park-like landscape (*i.e.* rapidly alternating grassland and forest) prevails. Although the European meadows are regarded as a product of human interference, it is quite likely that in its original state Central Europe was a mosaic of meadow and forest similar to the Far Eastern parklands.

HEATHS AND PEAT-MOSSES.—Edaphic factors are mainly responsible for at least two striking types of temperate vegetation, besides the coast formations (salt marsh, dune, &c.), namely heath and peat moss. The heath is a good instance of a PLANT ASSOCIATION, a small unit of vegetation consisting of one or more dominant plants accompanied by a number of subsidiary species. In this case a single plant is unquestionably dominant, to wit, *Calluna vulgaris*, the ling or heather. Extensive heaths are found in tracts of the cold-temperate belt which have a maritime climate, but only upon soil very poor in mineral salts generally, and in lime in particular. *Calluna* is usually accompanied by several other members of the same family (Ericaceæ), such as the Bell Heathers (*Erica Tetralix*, *E. cinerea*), Bilberry (*Vaccinium Myrtillus*), Cowberry (*V. Vitis-Idæa*), and Bearberry (*Arctostaphylos Uva-ursi*). For all these, including heather, it has been shown experimentally that their roots will not thrive in a soil solution of ordinary strength; the plants are, in fact, strictly adapted to a medium poor in mineral salts. Other subsidiary constituents comprise small birch trees (*Betula alba*), willow bushes (*Salix aurita*, *S. repens*),

tussocks of Hair Grass (*Deschampsia flexuosa*), and many plants which grow also elsewhere in sterile situations. Acid humus accumulates in the heath soil and renders it physiologically dry.

The last feature is still more marked in the peat-mosses or turbaries, which are common on damp soil in moist, cool climates, and consist chiefly of Sphagnum mosses. The structure of mosses of this genus enables them to absorb and retain very large quantities of water. The Sphagnum is continually dying off below, and growing on above, so that the surface of the bog becomes raised, especially in the middle, above the level of the surrounding land, upon a basis of compacted vegetable debris impregnated with dark-brown humic compounds and free humic acids, which retard the process of decay (Sphagnum peat). Among the living Sphagnum a few flowering plants are scattered, some of which are peculiar to the peat-moss (*Vaccinium Oxycoccus*, the genuine Cranberry).

The peat bog is very poor in mineral salts, especially in nitrates. Hence plants which partly satisfy the need of nitrogen by means of the insectivorous habit are largely inhabitants of such bogs (species of *Drosera*, *Pinguicula*, and *Utricularia* in Europe; in America, also species of *Sarracenia* and *Dionaea*). Turbaries are exceedingly abundant in Ireland, where they cover about one-seventh of the land surface.

ECONOMIC PLANTS.—Wheat (*Triticum* spp.), as the principal food plant of the most highly civilized peoples, ranks above all other economic plants, taking precedence even of rice. Barley (*Hordeum* spp.) extends farther north than any other cereal, and hence is locally valuable as a bread crop, while in lower latitudes it is extensively grown for malt. Bread made from rye (*Secale cereale*) is largely consumed in Germany and Russia, and the use of Oats (*Avena sativa*) for meal and fodder is well known. Maize (*Zea Mais*; over 300 races) prefers a warm-temperate, or even subtropical climate, and demands summer rains (or irrigation); though in common use for human food in Italy and Roumania, it is chiefly valuable as fodder for swine and poultry. The cultivation on a large scale of Sugar Beet (*Beta maritima*) dates back only to about 1811, but this plant now provides a larger proportion of the world's sugar supply than the sugar cane. The Mangold is a race of the same species. The Potato (*Solanum tuberosum*) is believed to be a native of the dry Andine highlands, but in cultivation it has a very wide geographical range, varieties of this plant being capable of cultivation from the Tropics to the farthest limits of agriculture, even beyond the polar limit of barley. In addition to its familiar use, its value as a source of starch and of alcohol should be noted. Buckwheat (*Fagopyrum esculentum*), though comparatively innutritious, supplements the cereals in Russia and the United States. The Vine (*Vitis vinifera*) requires a somewhat special climate if the production of good wine is desired; in particular, a long summer extending into a mild autumn is essential. Raisins and currants are further products of this plant. The Hop (*Humulus Lupulus*) is exacting in its soil requirements, and is a very local crop. The principal fruit tree is the Apple (*Pyrus Malus*). Bare mention must suffice for the following: Deciduous timber trees include Oak

(*Quercus robur*); Elm (*Ulmus campestris*, *U. montana*); Beech (*Fagus sylvatica*), Maple (*Acer* spp.); Walnut (*Juglans* spp.); Box (*Buxus sempervirens*); Jarrah and Karri (*Eucalyptus* spp.). The most important Conifers are: Scots Fir or Yellow Deal (*Pinus sylvestris*); Weymouth or White Pine (*Pinus Strobus*); Long-leaf or Pitch Pine (*Pinus palustris*); Spruce or White Deal (*Picea excelsa*); Larch (*Larix europea*); Douglas Fir (*Pseudotsuga Douglasii*); Pencil Cedars (*Juniperus* spp.); and Kauri Pine (*Agathis australis*). Flax (*Linum usitatissimum*) and Hemp are the chief fibre plants. Olive oil is obtained from *Olea europea*, colza oil from a species of *Brassica*—a genus which also includes cabbages, turnips,



Fig. 192.—Cacti (*Opuntia* spp.) on the arid plateau of Anahuac (Mexico)

and swedes. Tan is furnished mainly by the barks of various trees, especially oak, hemlock-spruce, and wattles (*Acacia* spp.). Finally, the importance of numerous grasses and Leguminosæ as pasture and fodder plants may be noted.

DESERTS.—In the northern hemisphere there are vast deserts, regions with a scanty rainfall (10 in. or less) and a meagre vegetation, situated mainly in the sub-tropical belt, but in some cases in higher latitudes. They comprise the Sahara, with its Asiatic continuations; a great part of Central Asia (Kara Kum, Gobi, &c.); and the country between the Rocky Mountains and the Sierra Nevada. Central Australia is the only large desert region south of the Equator, but smaller tracts occur in South-west Africa and on the west coast of South America.

In deserts the effects of prevalent drought are accentuated by great atmospheric dryness, by a wide annual range of temperature, and by violent daily fluctuations. Many desert plants are characterized by their dependence upon deep-lying subterranean water; accordingly their roots

are enormously developed and may penetrate to a depth of as much as 50 ft.

As a rule the shoots are so constructed as to retard transpiration (thorny or switch-like branches with reduced leaves, waxy or resinous coatings, &c.). Some of the most striking desert forms have that combination of xerophilous adaptations which is termed "succulence", notably the host of Cacti (fig. 192) and their "imitators" in other families (*Euphorbia*; *Stapelia*, *Huernia* and other Asclepiadaceæ); further, the different Aloe-like plants, some squatting on the ground like gigantic green bulbs (*Agave*), others putting forth a short stem (*Yucca* spp.) or even a well-developed branching trunk (*Aloe*, *Yucca brevifolia*).



Fig. 193.—*Welwitschia mirabilis*

Welwitschia mirabilis (fig. 193) is a very remarkable desert plant which grows in a few spots in the rocky wastes of Angola and Damara-land. The long main root is continued above into a short stout trunk which rapidly expands into a disc, depressed in the centre (sometimes nearly two-lobed) and deeply grooved just within the margin. The plant, which is covered by a reddish bark, rises no more than a foot above the ground, but an old specimen may be 5 or 6 ft. wide across the disc. Only two leaves are produced, which last throughout life; they are huge leathery belt- or ribbon-shaped structures, which soon become split up into a number of folded and twisted strips. The leaf grows continually from the base, which is hidden in the groove of the disc; from the groove also sprout short flowering branches bearing cones, which are the only outward marks that reveal the affinities of this peculiar plant with the more normal members of its class (Gymnosperms). The vegetative activity is sluggish but uninterrupted, and the plant may live for more than a century.

Since high salinity is a feature of many arid soils, desert plants frequently resemble strand plants (Halophytes) in general structure and in their power of enduring very concentrated soil solutions. Indeed, plants of the coast formations (salt marshes, maritime dunes, &c.) often reappear in inland deserts, or are there represented by closely allied species or genera. Thus the family of Chenopodiaceæ is equally characteristic of strand and of alkali lands. Sand-binding grasses flourish alike on maritime and on inland (desert) dunes; while *Spinifex squarrosus*, for instance, takes the place of our own Marram-Grass (*Psamma arenaria*) on the shores of the Indian Ocean, the very similar *S. hirsutus* is a familiar element in the Australian desert flora.

Annuals and perennial geophytes, which generally play a subordinate part in the desert flora, do not as a rule show very marked xerophilous adaptations in their short-lived vegetative parts. Their flowers are often large, delicate, and beautiful; thus the wilderness of Dzungaria is in its season a garden of lovely and fragrant tulips.

The desert does not support many useful plants. *Agave cochlearis* yields pulque, the national beverage of Mexico, while other species of the genus (and spp. of the allied *Furcraea*) supply valuable fibres (sisal hemp, henequen). Colocynth (*Citrullus Colocynthis*) and Aloe (especially *Aloe socotrina*) furnish purgative drugs. But by far the most interesting economic species of the sub-tropical desert is the date palm (*Phoenix dactylifera*), which in North Africa and in parts of Western Asia not only provides in its fruits the staple diet of man, horse, and camel, but is indispensable to the oasis-dwellers in a hundred other ways. Nowhere wild, it demands a considerable supply of water for its proper growth, but, on the other hand, does not flourish far from the desert belt.

ARCTIC ZONE.—Polar land vegetation has been studied chiefly in the northern hemisphere. The most important features of the Arctic climate are: the cold soil and air; the short summer with very long days; the long dark winter with frequent strong and dry winds.

Very many arctic plants are xerophilous, largely perhaps because the combination of cold ground and dry winds has a "desiccating" effect (vol. iii, p. 167); a similar cause may be responsible for the frequent occurrence, especially among woody species, of a dwarf or stunted habit of growth. The exceedingly brief vegetative period explains the sudden awakening and equally abrupt cessation of plant activity which so forcibly strikes the Arctic traveller.

TUNDRA.—The true Arctic formation is the tundra or frigid desert which lies beyond the northern tree limit. Here the ground is for ever frozen a few inches below the surface. Mosses (spp. of *Polytrichum*, *Bryum*, and *Hypnum*) or lichens (spp. of *Cladonia*, *Cetraria*, *Lecanora*) alone display any approach to luxuriance, and even these fail to occupy a portion of the ground, so that many bare patches are left. In moist places shallow peat-bogs develop; as Schimper points out, such spots physically resemble desert oases, whereas the true œcological representatives of the latter are sunny sheltered slopes, where the soil water becomes warm enough to be readily absorbed by roots.

In these heat-oases the surprising wealth of bloom and brilliancy of colouring of many Arctic flowers (Poppies, *Papaver nudicaule*; Forget-me-nots, *Myosotis* spp.; Jacob's Ladder, *Polemonium cæruleum*; Saxifrages, *Saxifraga* spp.) contrast strikingly with the barren monotony of the tundra. Only a single Arctic species deserves to be mentioned on the score of usefulness. This is the Reindeer Moss (really a lichen, *Cladonia rangiferina*), upon which the half-tamed reindeer herds of the Lapps and Samoyedes subsist for a great part of the year.



Fig. 194.—Montane Region

Northern face of a spur of Jakho (Simla). Coniferous forest of Deodars (*Cedrus Deodara*).

MOUNTAINS.—The ruling influence in the climate of high lands is the diminished atmospheric pressure, which not only reacts directly upon plants, but also brings in its train a number of secondary climatic effects, such as low temperatures, intense radiation, increase of rainfall up to a certain elevation after which diminution sets in again, rapid changes in the humidity of the air, continual movement of the atmosphere, and other factors, nearly all tending to produce intense transpiration, at any rate at certain times.

Climate of course changes as the altitude increases; accordingly mountain vegetation is arranged in a vertical series of *regions* and *belts*. On the loftiest tropical and subtropical mountains the following floral belts are distinguishable: (1) the Basal, and (2) the Montane regions of mountain woodland (figs. 194 and 195); (3) the Alpine region, comprising (a) the

Lower Alpine belt of mountain grassland, and (b) the Upper Alpine belt of mountain desert. Outside the Tropics, however, the last-named belt is often absent.

The basal and montane regions both have a flora of lowland type; but, whereas the former resembles the moist lowlands in the same latitude, the latter usually recalls lowlands of higher latitudes. On the Californian Sierra Nevada the scrubby chaparrals of the coast are replaced by conifer forest rivalling in grandeur the Pacific forest which



Fig. 195.—Montane Region

Southern face of another spur of Jako. Thin forest of Oak (*Quercus incana*) and Rhododendron (*Rhododendron arboreum*). Compare fig. 194. The difference in the vegetation of the northern and southern slopes depends partly upon the more protracted "snow-jacketing" of the northern face.

lies to the north of Mount Shasta; here, for instance, the Californian "big trees" (*Sequoia gigantea*), widespread in a former geological period, find a last refuge.

ALPINE REGION

The Alpine region most clearly illustrates the influence of the mountain climate. The flora is on the whole xerophilous, as might be inferred from the summary of climatic factors given above. It includes a certain number of Alpine forms of lowland species distinguished by shorter stems, smaller and thicker leaves, a larger root system, larger, brighter, more highly scented, and more richly honeyed flowers—characters which have been

shown by experiment to be in part due to the direct effects of climate,—but consists largely of true alpine species, among which some well-marked ecological types are conspicuous.

Cushion plants are common on all mountains in higher latitudes (many spp. of *Saxifraga*, *Androsace*, &c., on the Swiss Alps), but they are especially abundant and diverse in the Andine punas (alpine deserts) of Bolivia and Peru. The huge woolly cushions of the "Vegetable Sheep" (*Raoulia* spp.) characterize similar mountain deserts in New Zealand. Rosette perennials are regular constituents of lowland meadows (see p. 3), and this form of growth (many spp. of *Gentiana*, *Campanula*,

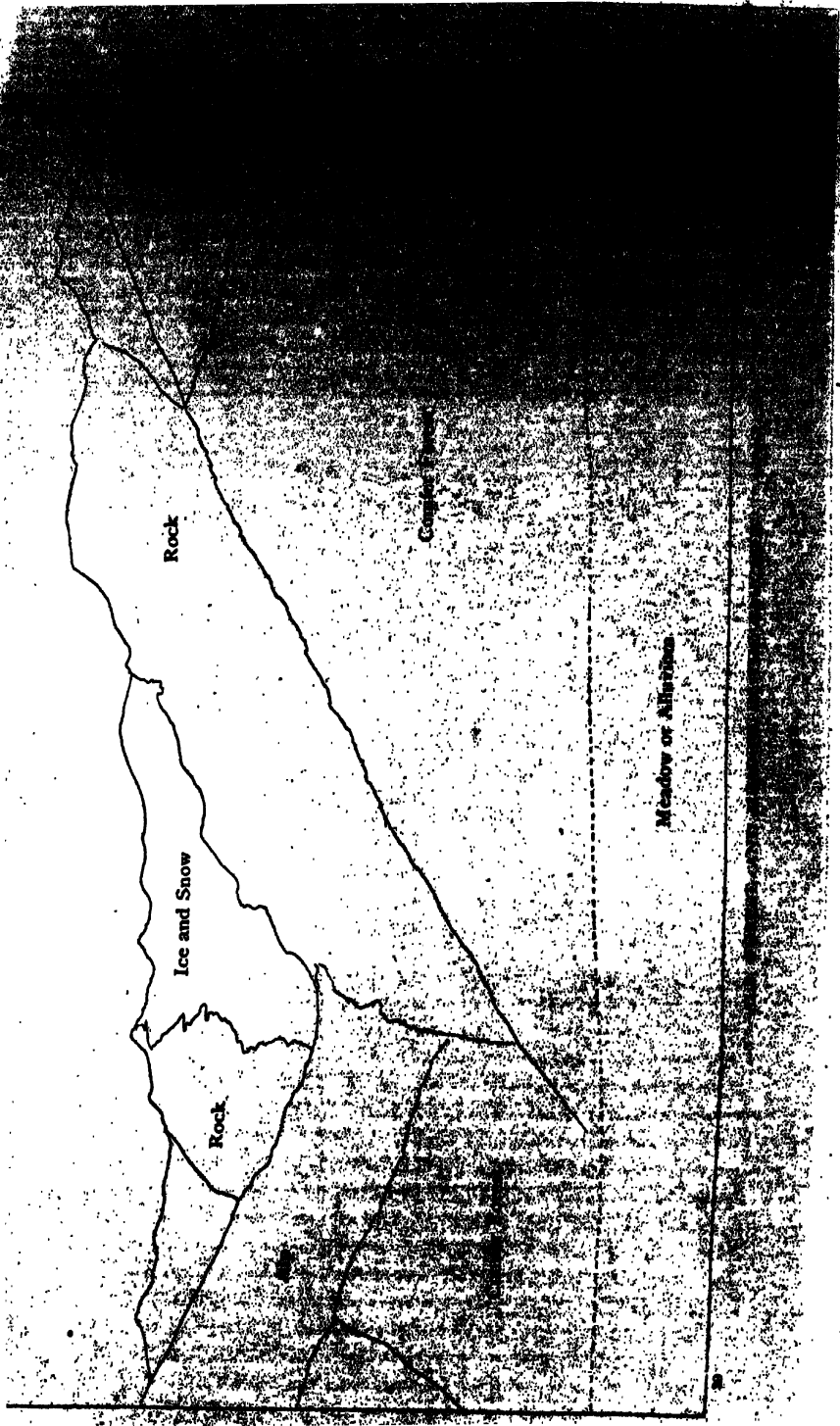


Fig. 196.—Alpine Region (Himalaya)

Cushion and rosette plants.

Primula, &c.) is in the alpine region also especially common in meadows (Alps) (figs. 196 and 197). Dwarf shrubs (e.g. the Alpenrosen, *Rhododendron ferrugineum* and *R. uliginosum*) and cushion plants recall similar types in the tundra. Indeed, there is an appreciable resemblance between the Arctic and alpine floras in Europe, and even identity of species in certain cases; similarly Mediterranean and South African lowland plants reappear on alpine heights in tropical Africa. But the agreement between Arctic and alpine vegetation is not nearly so close as is sometimes alleged, and even individuals of the same species growing in the two places differ considerably in structure.

The meaning of many striking alpine forms is as yet obscure. A case in point is the elfinwood type of tree, found just above the limit of normal tree growth, which has a short, gnarled, and bent trunk, bearing distorted branches and scanty foliage. In Switzerland this form is represented only by the very local *Pinus pumilio* ("Krummholz"), but similar





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trees recur on the majority of mountain ranges. From its mode of occurrence on tropical mountains at comparatively low levels this curious growth seems to have some connection with the "severance of the mountain mass into cones" and the consequent increased movement of the air.

Highly peculiar are the "Frailejon" of the alpine steppes (Paramos) in Venezuela and Ecuador. These are various species of *Espeletia* and *Culcitium* (Compositæ), remarkable for their tufts of sword-shaped leaves covered with dense air-entangling hairs, and in some species for their



Fig. 197.—Alpine Region (Himalaya)

A typical large-flowered alpine perennial; one of the Gentianaceæ, probably the same species as appears on the left of fig. 196.

massive stems thickly coated by withered remains of dead foliage. This grotesque type reappears, as regards general habit, in the lily-flowered *Vellozia* of the Brazilian highlands and in the giant ragwort (*Senecio Johnstoni*) of Kilimanjaro.

SEQUENCE OF REGIONS—UPPER LIMIT OF VEGETATION.—The sequence: Deciduous forest—conifers—birches or alders, and elfinwood—alpine herbs and dwarf shrubs—appears to be very constant upon temperate mountains. The plate gives a general view of conifer forest (*Picea orientalis* and *Abies Nordmanniana*), alp and eternal snows in the Caucasus, and fig. 198 shows avalanche-swept birches (*Betula Jacquemontii*) marking the tree-limit (alt. 13,000 ft.) in a Kashmir pass. A certain number of flowering plants contrive to exist on even the highest alpine summits in Europe; species of *Saussurea* (Compositæ) flourish

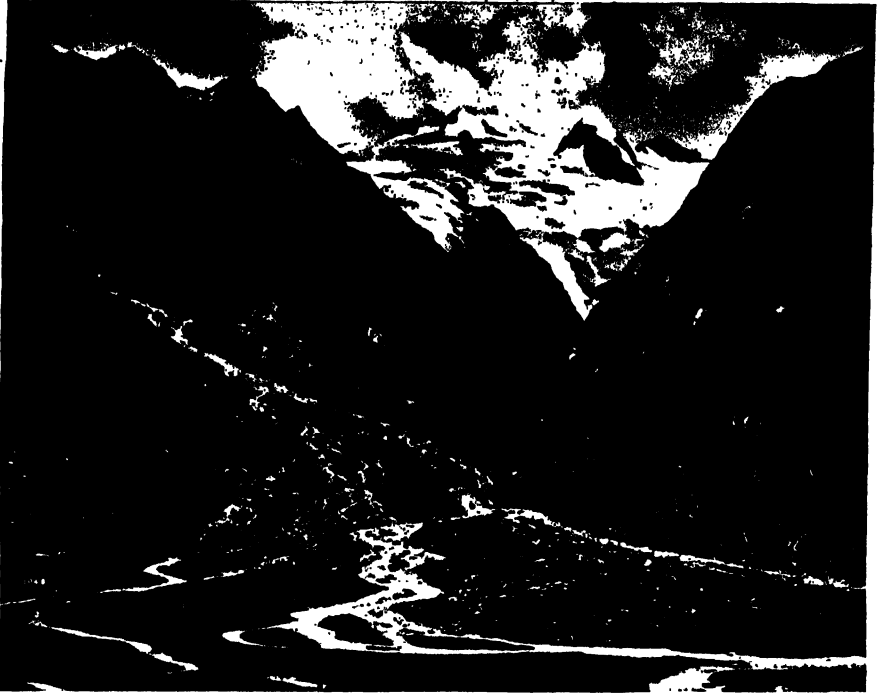


Fig. 198.—Limit of trees in the Zoji La Pass, Kashmir

at 19,000 ft. in Western Tibet; and lichens grow on the top of Kilimanjaro (19,200 ft.). Low forms of plant life are perhaps not wanting even on the highest peaks of the globe.

CHAPTER IV

AQUATIC VEGETATION

FACTORS.—Water, in large masses, offers an environment far surpassing the dry land in general uniformity and in local constancy. The very considerable differences which nevertheless exist between the floras of separate parts of the ocean, or between those of bodies of fresh water, must to a great extent be ascribed to historical causes, and are hence largely outside the scope of the present discussion. Ecological factors, of which light is here the most important, especially influence the *vertical* distribution of water plants. Thus decrease of light fixes the lower limit of coloured vegetation at a depth which varies within a considerable range according to other circumstances (turbidity of the water, &c.).

A muddy bottom is most favourable to plants rooted in lakes, while these thrive best on a rocky bed in rapid streams and in the sea. Apart

from the fundamental contrast between fresh water and the sea, chemical differences are even more local in their action than they are on land, though over limited areas their influence may be very great.

THE OCEAN.—The marine flora is characterized by the absence of Mosses and Ferns, the scarcity of Flowering Plants and Fungi, and the abundance of Green, Brown, and Red Algæ—the typical seaweeds. Bacteria, however, must not be overlooked, as they perform important functions, notably in connection with the circulation of nitrogen, here as on land. The fixed vegetation of the sea floor is termed the (vegetable) *benthos*, and is further subdivided into an emerging belt, exposed at low water, and a submerged belt. The freely floating plants—a very characteristic part of aquatic vegetation—constitute the (vegetable) *plankton*.

BENTHOS.—The marine benthos is more luxuriantly developed in high latitudes than in the Tropics, although the great accumulation of drifting pieces of Sargassum in the "Sargasso Sea" testifies to the abundance of these large Wracks on the coasts of Florida and the West Indies. The brown seaweeds especially, which everywhere are most conspicuous in the ocean flora,

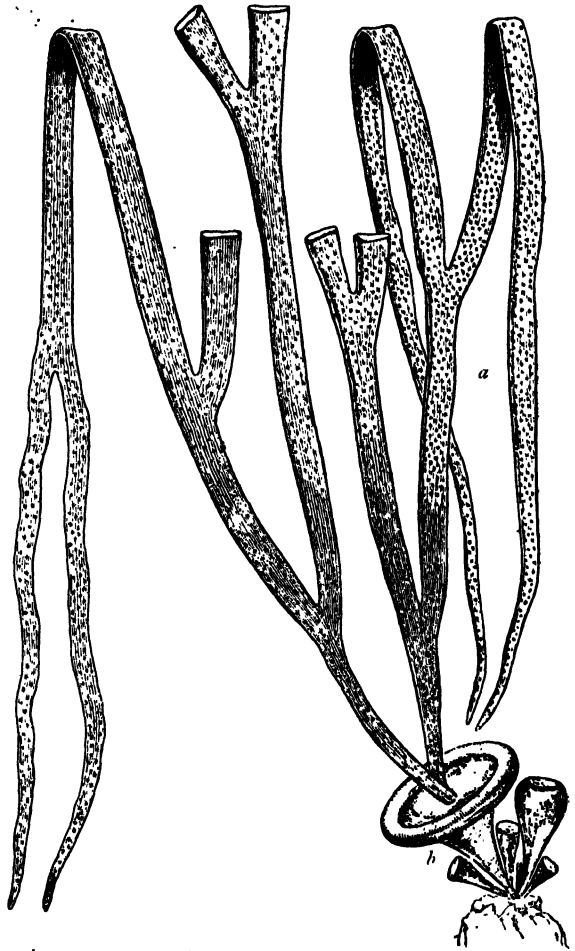


Fig. 199.—*Himanthalia lorea*

a, Part of an adult plant (reduced). b, Young plants.

reach enormous dimensions in temperate seas. *Macrocystis pyrifera*, large fronds of which may be over 600 ft. long, grows in rather deep water. But except for such giants the large seaweeds are generally found in the lower part of the emerging belt. Many of them show distinct adaptations to surf-beat, for example *Himanthalia lorea* (fig. 199), the leathery thongs of which swing with the ebb and flow, and undulate in harmony with the waves, while the top-shaped base offers little hold to breaker or eddy. In the submerged belt the grading influence of light is most evident. In

the Mediterranean many algæ (especially red forms) are strictly confined to shaded spots, even at great depths, while others (*Padina*, Plate, fig. 13, *Acetabularia*, Plate, fig. 7), which usually possess light-reflecting hairs or similar protective arrangements, inhabit bright places.

PLANKTON.—The vegetable plankton of the sea consists of microscopic algæ, among which the two brown groups of Diatoms and Peridineæ play the chief part. Like all plankton organisms these possess manifold devices for the enlargement of surface and the diminution of density, whereby they are enabled to float permanently near the surface (see below, p. 15). From the practical point of view they are of enormous importance, since they form the ultimate source of food for most of the abundant animal life of the ocean. The economic value of seaweeds (and of large water plants in general) is but slight.

LAKES

THE LAKE OF CONSTANCE.—The plant life of the Lake of Constance may serve not only to illustrate one aspect of freshwater vegetation, but also to indicate the problems which have to be attacked when the œcology of a limited area is studied in detail.

SOME PHYSICAL FEATURES OF THE LAKE.—The strong *surf* is a feature which has a marked influence upon the flora. Important also is the seasonal variation in the *water level*, which amounts to 6 or 7 ft.; late summer and autumn constitute the period of high water. At the surface the mean *temperature* of the water is about 10° C., with an annual range of 20° C.; for the air over the adjacent land the range is much wider, and the average is lower, namely 8° C. Both mean temperature and annual range diminish gradually with increasing depth down to 325 ft. Below that level there is a constant temperature of 4° C.; the heating effect of summer, however, is hardly felt below 100 ft. The average depth to which visible rays of *light* penetrate (as measured by the visibility of a white disc) is 35 ft.; the maximum, where the water is clearest, 75 ft.; but action upon a sensitive photographic plate takes place at far greater depths.

CLASSIFICATION OF THE FLORA.—The term "lake vegetation" is here interpreted so as to include not only the inhabitants of the "lacustrine region", which extends from low-water mark outwards, but also the borderland population between high- and low-water levels. The lacustrine vegetation comprises four principal types. The floating flora (plankton) reigns supreme over the deeper portions of the basin, while the floor of the same parts is occupied by the deep-water, fixed or resting organisms (deep-lying benthos). Near the bank the littoral benthos (shallow-water bottom vegetation) plays the chief part. Upon the surface lies the *pleuston*, which is, however, but poorly represented in the Lake of Constance.

PLANKTON.—The plankton, as usual, consists largely of Diatoms, of which the commonest and most characteristic are species of *Cyclotella*, with drum- or tambourine-shaped cells. One species occurs in a remarkable compound form which is not found elsewhere (fig. 207, 3); a number

of cells are arranged at intervals around the edge of a disc of jelly, in such a manner that the colony offers a large surface to the water in two planes at right angles to one another. The whole structure may be compared—for want of a better simile—to an old-fashioned undershot waterwheel, the cells occupying the position of the floats. Plentiful also is a species of *Ceratium* (Peridineæ), the cells of which have three long spines or horns serving to increase the surface (fig. 207, 1).

The curious green alga *Botryococcus Braunii* congregates in vast numbers in the uppermost layers of the water. It is made up of a number of cells embedded in the surface of a gelatinous hollow sphere, and produces great quantities of fat. In the first instance this serves as a temporary store of food within the cells; but the surplus is excreted into the ground substance, which becomes literally soaked in oil. The high oil-content probably explains the exceptionally great buoyancy of this alga, although the suggestion has been made that gas bubbles also assist in the lightening of the structure, as they certainly do in the case of some blue-green plants (Cyanophyceæ). The minor constituents of the plankton are to a great extent Diatoms, among which *Stephanodiscus Astræi* alone need be named. This species is rarely found so far south, and in the Lake of Constance is certainly a relic of glacial days.

The above constellation of principal species is not exactly reproduced in any of the other European lakes hitherto examined. In the "Grosse Plöner See", in Holstein, for instance, the dominant elements are very different, although some of the minor forms are the same. Here the fragile ribbon-colonies of *Melosira* (Diatoms) abound, and the surface waters are full of gas-buoyed Cyanophyceæ. The contrast in these particular respects no doubt depends upon existing (œcological) factors. In the Lake of Constance surf would quickly demolish the *Melosira* ribbons, while most Cyanophyceæ are not content with the small amount of organic matter contained in its pure waters. But many such peculiarities of aquatic (as of terrestrial) floras are due to historical causes; witness the case of *Stephanodiscus* just quoted.

It is of some interest to enquire how far down the plankton flora extends. For the Swiss lakes the most definite answer that can be given is to the effect that Diatoms are still abundant at the greatest depths so far examined for plankton (180 ft., Constance; 290 ft., Zurich). So little light penetrates to these depths that coloured plants cannot be supposed to live there permanently. On the other hand, if all the Diatoms met with below, say, 100 ft. compose a shower slowly falling to destruction, then a corresponding number of corpses in the form of their resistant siliceous walls should be found on the bottom. As this is certainly not the case, we must conclude that the Diatoms found at these great depths are merely enjoying a temporary dive, possibly in connection with some process of rest or reproduction, and that they subsequently return to the higher levels.

Such displacements no doubt largely depend upon the play of currents, and are consequently passive and irregular; but there seems to be no reason why these plants might not alter their specific gravity in

a more "voluntary" manner by means of chemical changes in the cell contents. In the lake, as in the ocean, the plankton is the ultimate source of food for nearly the whole of the animal population. Some of the small crustaceans in particular at times live exclusively upon *Cyclotellas*.

DEEP-LYING (ABYSSAL) BENTHOS.—On the ocean floor Bacteria have been found in considerable numbers at a depth of 3600 ft. (24,000 per ccm. of mud in the Bay of Naples), and seem to die out only below 4900 ft. Hence it is probable, although direct proof is wanting at present, that a permanent bacterial flora inhabits the mud in the deepest parts of the lake (250–800 ft.), whereas the few Diatoms which are known to occur there are no doubt casual immigrants from shallower places. Even at 240 ft. the only native inhabitants are Sulphur-Bacteria (*Beggiatoa* spp.), and an almost colourless *Oscillaria* (Cyanophyceæ), while the accompanying Diatoms and Green Algæ (e.g. *Scenedesmus quadricauda*, fig. 205, 9) have almost certainly strayed from the higher regions in which they are at home.

With increasing shallowness of the water the flora becomes quite gradually richer in coloured forms (especially Diatoms), and a sharp definition of the littoral benthos is possible only with reference to megaphytes (that is to say, large many-celled plants).

LITTORAL BENTHOS AND PLEUSTON.—Freshwater megaphytic vegetation, in marked contrast to that of the sea, consists chiefly of Higher Plants and very largely of Angiosperms. The latter dominate the shallow waters—of a depth of 20 ft. or less—in the Lake of Constance, although megaphytes in the shape of Stoneworts (Charophyta) extend as far down as 100 ft., a depth which may be regarded as roughly fixing the lower boundary of the littoral region.

Prominent among these Flowering Plants are various Pondweeds (spp. of *Potamogeton*, fig. 225), all submerged plants with prostrate stems rooting in the mud, and long slender ascending branches bearing numerous thin flat leaves; internally they show a general simplicity of structure, and in particular a very feeble development of conducting and strengthening tissues and an abundance of large air spaces, anatomical characters which are common to most submerged flowering plants, and evidently connected with the nature of their environment (general simplicity and uniformity of conditions, slight demands upon mechanical strength, poor ventilation of the lower organs, &c.).

Canadian Water Weed (*Elodea canadensis*) accompanies the pondweeds, and has a very similar structure. The Water Milfoils (*Myriophyllum* spp.) differ mainly in their foliage, which is very finely divided. This "gill" type of assimilating organ is not uncommon among submerged plants; it combines pliancy with a large exposure of surface.

The influence of the strong surf is shown by the scarcity of plants of the water-lily type; that is to say, rooted forms with large leaf-blades which float upon the water surface. For the same reason Duckweeds (*Lemna gibba* and *L. polyrrhiza*) are the only representatives of the pleuston in the strict sense; but it is convenient to class with them also rootless plants which float freely under water, like the Bladderworts, fig. 234

(*Utricularia vulgaris* and *U. minor*), and the abundant Hornwort (*Ceratophyllum demersum*).

Two social marsh plants which raise their assimilating organs above water are characteristic of the shallowest part of the bank region, namely, the Giant Sedge or Bulrush (*Scirpus lacustris*) and the even taller Reed (*Phragmites communis*). The former is the more pronounced aquatic of the two; its rhizomes (rootstocks) creep on the bottom, producing leaves under water, and sending into the air only leafless green haulms to a height of about 12 ft. The rhizomes of the Reed bore deep down into the mud (as much as 5 ft.) and give rise to a dense feltwork of roots firmly binding the ooze together, by which means excellent support is given to tall aerial shoots (as much as 15 ft. high) with well-developed leaves.

On the other hand, the Reed cannot produce submerged leaves, nor can its ordinary leaves survive in the submerged condition; and indeed the plant hardly extends beyond a depth of 6 ft. Nevertheless, the Reed belt in sheltered spots encroaches appreciably upon the lake, advancing in favourable cases by 10 ft. per annum. It is chiefly the mud-collecting capacity of *Phragmites* that enables it to reclaim land in this way; but it is also aided by its very peculiar habit of sending forth runners which creep upon the water surface for great distances (40 ft. or more).

Innumerable Diatoms (especially mucilage-sheathed or -stalked species of *Encyonema*, fig. 207, 7, *Cocconeis*, or *Gomphonema*, fig. 207, 6a), and Green Algæ (*Spirogyra adnata*; spp. of *Edogonium*, Plate, fig. 9, *Coleochaete*, fig. 206, 2 and 3, and *Aphanochete*, Plate, fig. 8) encrust the stems and leaves of the megaphytes, or adhere in dense masses to stone and woodwork. Some species prefer the well-aerated spray-zone—that is, the strip of shore which is for the time directly exposed to surf beat; for instance, *Tolypothrix penicillata* (Cyanophyceæ), which withstands the most violent waves, and, in quieter spots, spp. of *Ulothrix* and *Cladophora* (Green Algæ) and of *Rivularia* (Cyanophyceæ). Entangled among these masses of fixed algæ float numerous unattached species, especially Green Algæ (*Scenedesmus*, *Pediastrum*, *Cosmarium*) and Cyanophyceæ (*Merismopedia*).

THE BORDERLAND.—The spray-zone, with its flora of algæ, is necessarily variable in position; but the strip of territory within which it moves, the borderland belt, has a permanent and very characteristic flora of Flowering Plants. The inhabitants of the lower portion of this strip are partly land forms of lacustrine species (for instance, Pondweeds) and partly land plants adapted to more or less prolonged submersion. Prominent among the latter are three species with quill-like aerial organs, which are leafless shoots in Spikerush (*Eleocharis acicularis*), leaves in Shoreweed (*Littorella lacustris*), and bladeless leafstalks in Lake Buttercup (*Ranunculus reptans*). All three further agree in the possession of long, slender, creeping rhizomes or runners. Noteworthy is a beautiful dwarf Forget-me-not (*Myosotis Rehsteineri*), which is absolutely confined to gravelly places within the border zone of the Lake of Constance and a few other Swiss lakes.

The plants mentioned show adaptation to surf beat, especially in their

squat growth and in the frequent "quill" form, both features being least marked in the individuals which grow farthest from the lake. On the land side, in fact, the flora passes over into that of the adjacent marshes.

CHAPTER V

GENERAL AND APPLIED ŒCOLOGY PHYLOGENY

The preceding chapter is based upon the valuable account of the flora of the Lake of Constance which we owe to Kirchner and Schröter. Their excellent work deals chiefly with the composition of the flora and with the distribution in space of the principal species. On the Œcological side little is attempted beyond an indication of some of the problems which await further investigation.

The earlier researches of Count Zeppelin and others provide much information regarding the physical and chemical features of the lake. But untouched as yet in this case are certain other preliminary lines of work, notably: (1) The preparation of a statistical record of the flora, preferably by means of maps; for each species, (2) an experimental study of its physiology under normal conditions, and (3) a determination, likewise experimental, of modification in its structure and behaviour resulting from changes in environment.

Thus a problem of limited scope, dealing largely with simple organisms in relation to a comparatively uniform medium, assumes, upon closer inspection, a formidable complexity. On dry land both plant and environment are on the average more intricate than is the case in the water, while the Œcology of cultivated plants is still further complicated by the distorting influence of "one-sided" adaptation.

CORRELATION OF FUNCTIONS.—So far, argument has centred principally about single factors of the environment or single functions of the plant. The physiologist, indeed, for the present confines himself almost entirely to analytical work, and rightly so, since this is "fundamental and logically prior" to the synthesis of vital activity to which he ultimately aspires. While this synthesis is in itself, as yet, merely an ideal, the existence of actual correlations between functions which are conventionally treated as if they were quite distinct is a fact which has long been recognized, but which is only now receiving the attention it merits. We are just beginning, for example, to attack the intensely interesting problem of the chemical reactions which accompany the reception of stimuli. Czapek has shown that a particular chemical reaction which is always proceeding in the living root-tip cells of the Bean undergoes a characteristic change when the roots are displaced from their normal position (which is vertical in the case of the main-root) with reference to the "direction" of the force of gravity.

The behaviour of Mother-of-thousands (*Linaria Cymbalaria*), fig. 200, suggests even more interesting possibilities. Here the stalk of the unpollinated flower invariably grows so as to point towards the brightest light, whereas after pollination this relation is exactly reversed. It is generally admitted that fertilization—to which pollination is a prelude—involves the application of a “chemical stimulus” whereby the egg cell is made to resume activity. Is it possible that in the case of *Linaria* a chemical *compound* introduced by the pollen grain causes the reversal of light sensitiveness in the flowerstalk? The question is raised to illustrate one type of problem which is likely to receive much attention in the near future.

CORRELATION OF FACTORS.—A combined action of different factors of the environment has on various occasions already been implied if not

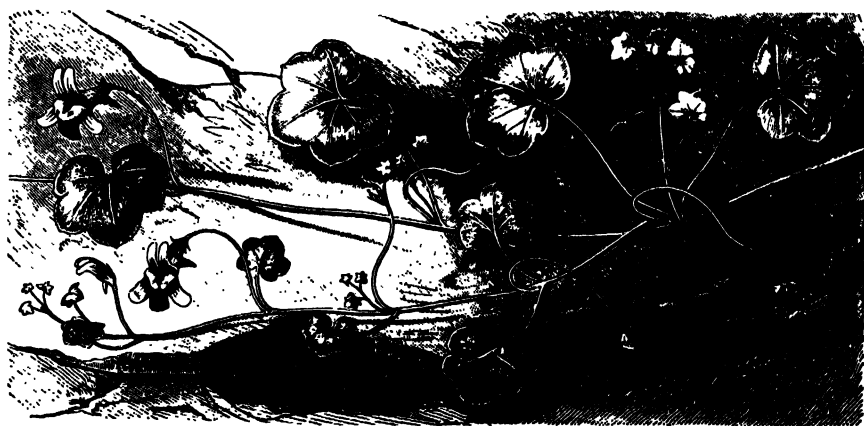


Fig. 200.—*Linaria Cymbalaria* ("Mother-of-thousands")

On the left: Flowers. In the middle: Unripe fruits. On the right: Ripe fruits.

emphasized. Special importance attaches to a particular kind of interaction which has been pointed out by Dr. Blackman under the name of the principle of “limiting factors”, and defined by him as follows: “When a process is conditioned as to its rapidity by a number of separate factors, the rate of the process is limited by the pace of the ‘slowest’ factor.” Self-evident as this proposition appears when stated in so many words, the relation which it expresses had previously been overlooked to a remarkable extent. One application of this principle may be found in the conclusion that the numerous plants which undoubtedly strive for the brightest illumination of their shoots do so for some reason at present unknown, and not, as has been widely assumed, for the sake of increased carbon-dioxide assimilation, since the maximum rate of the latter process is in nature “limited” at a low level by the small percentage of carbon dioxide in the atmosphere.

ŒCOLOGY OF CULTIVATED PLANTS.—The œcological “disharmony”—to borrow a term from the author of the *Nature of Man*—which characterizes cultivated plants has been referred to above more than once,

and the imperfection of existing œcological knowledge is plainly in evidence in every account of natural vegetation. Nevertheless many general problems of economic botany may even now be profitably discussed from the standpoint of œcology, if only with a view to the definition of future lines of work.

ACCLIMATIZATION.—It has been said that vegetation determines the manner of life of human communities. This statement is most obviously true in the case of primitive, uncivilized communities. The almost entire dependence of the Guarani Indians of the Orinoco delta upon a single palm—the Burity (*Mauritia flexuosa*), mentioned in a previous chapter (Vol. III, p. 176),—is a classic instance. With increasing civilization man shows less passive adaptation to the vegetation around him, but exerts a correspondingly greater modifying influence thereon. Colonizing peoples particularly are interested in the widest possible dispersal of the best economic species. Hence, for our Empire at least, the acclimatization of plants is a problem of very great importance. Considered in the widest sense, acclimatization may be held to comprise all cases in which a plant is introduced to new surroundings and survives without serious injury. On the other hand, the term is often employed in a narrower sense, and implies a deliberate attempt on the part of man to extend the range of some useful species to a climate appreciably different from that in which it is known to thrive. It will here be convenient to accept the wider interpretation, but to pay special attention to the practical side of the matter.

We may distinguish at least two degrees of human effort on behalf of the wider dispersal of useful species. In the majority of cases man merely transfers a plant to a congenial climate across intervening obstacles. Thus, the enthusiastic praise bestowed by Captain Cook upon the Bread-fruit (*Artocarpus incisa*) stimulated the British Government to attempt the introduction of this valuable food plant into the West Indian colonies. After a preliminary failure a cargo of young trees was in 1783 safely conveyed from Tahiti to St. Vincent, and there planted. Thence the plant has spread over the whole of the American Tropics.

Hitherto the geographical range of a cultivated plant has usually been regulated by commercial rather than by botanical considerations. The history of an important industry based on the culture of a foreign plant is frequently found to start from the time when some native or previously naturalized industry was in the act of perishing. The Ceylon tea-gardens, which now have an output of the annual value of over three million sterling, practically owed their origin to the destruction of the coffee plantations by an incurable fungus epidemic (caused by *Hemileia vastatrix*) in the latter half of the nineteenth century.

Sometimes the problem to be solved is that of the discovery of some crop which will flourish under peculiarly inhospitable conditions. An instance is furnished by the gorse culture, practised on a very large scale in the "landes" of Brittany and Normandy. The gorse or furze (*Ulex europæus*) can be grown with profit upon ground otherwise very infertile, and yields fodder little inferior to the finest clover. It is worth

noting that the value of furze as a forage crop would be greatly enhanced if a spineless race could be "fixed". Isolated specimens bearing this character have occurred in cultivation from time to time, but so far have not been found to breed true. It is most probable that the failure of attempts in this direction is partly due to lack of sufficiently prolonged and careful breeding experiments. Moreover, chemical analysis has shown that the spiny green shoots are the most nourishing parts of the plant, so that the aim which has to be kept in view is the "blunting" of the thorns rather than any reduction of their dimensions.



Fig. 201.—Acclimatization. Avenue of *Oreodoxa* Palms at Sibpur

Both the Palm and the *Agave* in the foreground are American plants; they are however quite at home in the Calcutta climate.

But little success—far less than is commonly assumed—has hitherto attended attempts to bring about that more advanced type of acclimatization in which the constitution of the plant is seriously and permanently altered to suit a new environment. Many a species thrives as well as in its home, or even shows an improvement, when transferred to a climate which is only slightly *warmer* than that to which it is naturally accustomed. A familiar feature of such cases is the fact that development becomes much more rapid, while the span of life is considerably shortened. Accurate observations with regard to this point have, however, been made only to a very limited extent, and usually upon timber trees, so that hardly anything is known concerning the *amount* of accommodation of which any species is capable; further, it is quite uncertain how far such alterations become hereditary.

One of the classical instances of acclimatization is that recorded in 1841 by Metzger, in which a high-grade American Maize (*Tarascora* Corn) was "transformed" within three years after transportation to Germany into the inferior form commonly cultivated in the latter country for poultry-feeding purposes. This case was quoted by Charles Darwin as the most remarkable instance known to him of the direct and prompt action of climate on a plant. Yet, if the recent criticism of de Vries is correct, it appears to have been rather a case of hybridization of the American with the European race, followed by a struggle among the



Fig. 202.—Acclimatization. The Avenue of Lombardy Poplars at Srinagar

The Lombardy Poplar (*Populus dilatata*, Ait.) is a tree of obscure origin, possibly derived from Central Asia or Western China. In Kashmir it is found planted throughout the valley, but always in flat places, where it is liable to inundation. It withstands floods of 6 to 8 feet in depth, and extending over several weeks. The avenue is here shown as it appeared during the great flood of 1903.

resulting mixture of parent- and hybrid-forms, in which the best-adapted (*i.e.* the European) race gained an early victory. The accommodation by shortening or shifting of the growth period which often occurs when cereals are transferred to a higher latitude or altitude is also evidently in part the result of an unconscious selection by the grower, since at first only the most rapidly developing individuals will succeed in thoroughly ripening their grains. As yet hardly anything is known about accommodation in relation to factors other than temperature.

The want of success which has hitherto prevailed in the bulk of acclimatization work is certainly in part due to want of appreciation of the very *indirect* relation which usually exists between a stimulus and the response that it calls forth. This is only one aspect of the reluctance, too frequently shown by the practical man, to admit the inconvenient complexity of physiological problems. It seems quite possible that good

results might be obtained if, instead of trying to force an organism to a direct response in the sense desired, experimenters were content to apply all available means of "upsetting the equilibrium" of a race, and to select the most promising among the new forms, should such arise in consequence of this treatment.

THE HISTORICAL FACTOR IN PLANT GEOGRAPHY

The present geographical distribution of a given species of plant is determined not only by its existing œcological relations, but also by the



Fig. 203.—Nil Nag, Kashmir

past history of the species. A couple of examples must suffice to illustrate this well-established fact.

NIL NAG.—The Nil Nag is a mountain tarn situated 6800 ft. above sea level on the northern slope of the mountain chain which bounds the valley of Kashmir on the south and divides it from the plains of the Panjab. This southern chain, of which the peaks reach a height of 17,000–18,000 ft., has a temperate flora on its northern face from about 5000 ft. (that is from the valley, which nowhere lies below this elevation) upwards, thereby differing radically from the whole of the *Himalaya* west of the Chenab River, which—except in very circumscribed and scattered areas—at the same elevation has a mainly sub-tropical vegetation. The margin of the lake supports at the present day an almost European flora.

The tree (fig. 203) in the foreground is a *Cratægus*, usually referred to *C. Oxyacantha*, Linn., of which the common English Hawthorn is regarded as a form. Some of the tall trees on the left are specimens of *Pyrus*

lanata, Don, a close ally of the White Beam of Central Europe. Along the shore is a belt of *Scirpus lacustris* (Bulrush) and the allied *Cladium Mariscus* (Twig-rush), together with *Ranunculus Lingua* (Great Spearwort), *Lythrum Salicaria* (Purple Loosestrife), and other well-known British species. Several of these plants recur at various places in the Kashmir valley but, outside the latter, are foreign to the Indian flora. An even more remarkable case of such "sporadic" distribution is afforded by *Lysimachia vulgaris* (Yellow Loosestrife), which is known in the Indian region solely from a single spot in the delta of a mountain stream flowing



Fig. 204. — Northern Slope of Sakesar, Panjab Salt Range. Scrub consisting mainly of Olive and Box

into the Wular lake at the western end of the Kashmir valley; in this locality, however, it is unquestionably native.

SAKESAR.—Mount Sakesar (fig. 204) is the point at which the Panjab Salt Range—which has so far run parallel to the course of the Jhelum—trends sharply to the north-west. The physical conditions on the mountain are of the desert type, comprising as they do a small and erratic rainfall, a very dry atmosphere, a wide temperature range, and a very pervious soil, locally impregnated with rock salt and other minerals. Hence the generally xerophytic character of the vegetation is in accordance with expectation. Ecological considerations do not, however, explain why the flora of the southern face is that of sub-tropical Western India (Jujube, Indigo, *Lantana*), whereas on the northern slope Western Asian (*Eremurus*) and Mediterranean (Box, Olive) types prevail, mixed with Himalayan Oak (*Quercus incana*), Bluebell (*Campanula*) and St. John's Wort (*Hypericum*).

PHYLOGENY

The historical factor in plant geography is of interest chiefly in connection with the problem of the origin of species through descent, while in return the facts of geographical distribution are important to the student of phylogeny.

Perhaps in no other branch of botanical research do the results at the present day comprise so little of undisputed fact, and so much of individual opinion and interpretation, as is the case in this study of phylogeny. Yet when the attempt is made to deal, in a very limited space, with the enormous variety of structure displayed by the plant world, a certain positiveness in the manner of treatment is inevitable. The various theories concerning the modes of evolution are considered elsewhere. A word may, however, be devoted to the methods of phylogenetic study.

The end of phylogeny, namely the full understanding of the natural system of organisms, is an ideal even less attainable than the aim of physiology. In examining the ancestral tree of the living world we gaze upon the outside of the dense and variegated canopy of existing species; the graded differences and resemblances among the latter only vaguely suggest how they are really connected with one another, and it is but rarely that the observer is granted a glimpse of the actual scheme of branching. Moreover, the course of many branches is crooked and erratic, so that frequently members which have no close affinity with one another stand side by side in a misleading manner.

Two ways of attempting to gain a deeper insight into this marvellous structure suggest themselves. We may endeavour to draft in bold outline an approximate plan of the main branches which presumably determine the great groups (phyla) in which the outer members are evidently parcelled out. The basis of this method is that Comparative Morphology which tries to fix the true limits of a phylum, to link up the types within a group into probable series, and to indicate all possible connections between different phyla.

On the other hand, the enquirer may deliberately confine his attention to a very small set of forms which appear to be closely related to one another, and deal in the first instance only with the simplest units. This method directly involves the questions of the definition of species and of the factors controlling evolution; it is closely bound up with the study of geographical distribution and lends itself to experimental treatment, although the possibilities of the last development have hardly yet been tested.

There is no inherent opposition between these two methods, but at most a difference of immediate aim or, perhaps, rather of mental attitude; and sound research cannot afford to ignore either instrument. But for the present it is simple comparison on broad lines that must furnish most of the facts for the brief survey and tentative scheme of the principal tribes of plants which will mainly occupy our attention in the succeeding chapters.

BOTANY

CHAPTER VI

ALGÆ

THE FLAGELLATE ANCESTRY OF ALGÆ.—The theory of the Flagellate ancestry of Algæ ranks among the most interesting of recent phyletic advances. Bound up with this theory is the view, now widely accepted, that for the classification of the Lower Plants (Thallophytes) minute (cytological) characters of the individual cells are of prime importance, even in the case of the bulky many-celled types. Experiment has indeed shown that the kind of reproduction and the form of plant body, characters upon which at one time reliance was chiefly placed, are of very restricted value as tests of affinity.

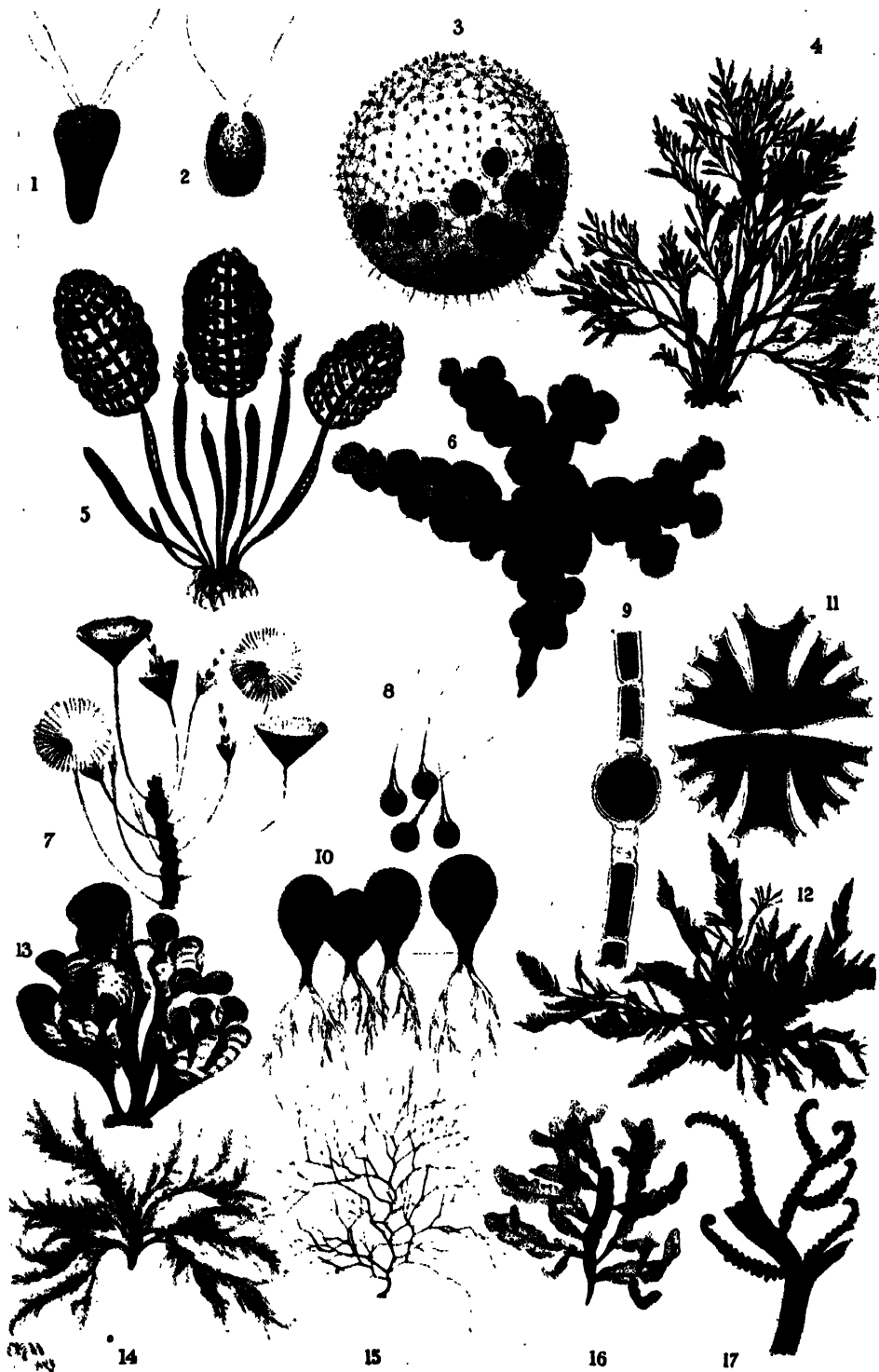
FLAGELLATES.—A FLAGELLATE is a microscopic creature of simple form and structure consisting typically of a single cell devoid of any firm containing membrane. All Flagellata swim about in water or some other liquid during the whole of their active existence by means of one or more delicate protoplasmic “lashing-threads” or *flagella*. The majority are saprophytes, living upon organic matter dissolved in the medium in which they swim. But many have the power of taking in solid nourishment in animal fashion, while others work up their food substances in the cell from simple compounds like carbon dioxide after the pattern of green plants (prototrophic nutrition). The same species may vary its method of feeding according to circumstances. The prototrophic forms further agree with green plants in the possession of *chromatophores*, the special organs for photosynthesis, and of starch grains or other obvious *reserve bodies* representing the surplus of assimilated material.

Flagellates multiply by symmetrical bipartition; apart from this division there is no special reproductive process, and the organisms are devoid of any mortal body or “soma” (physiological immortality; see GENERAL BIOLOGY). A transitory resting stage (encystment), during which a resistant membrane is secreted, may occur under unfavourable conditions. In some cases several individuals may combine loosely to form a “colony”, but the typical Flagellate leads a roving and single life.

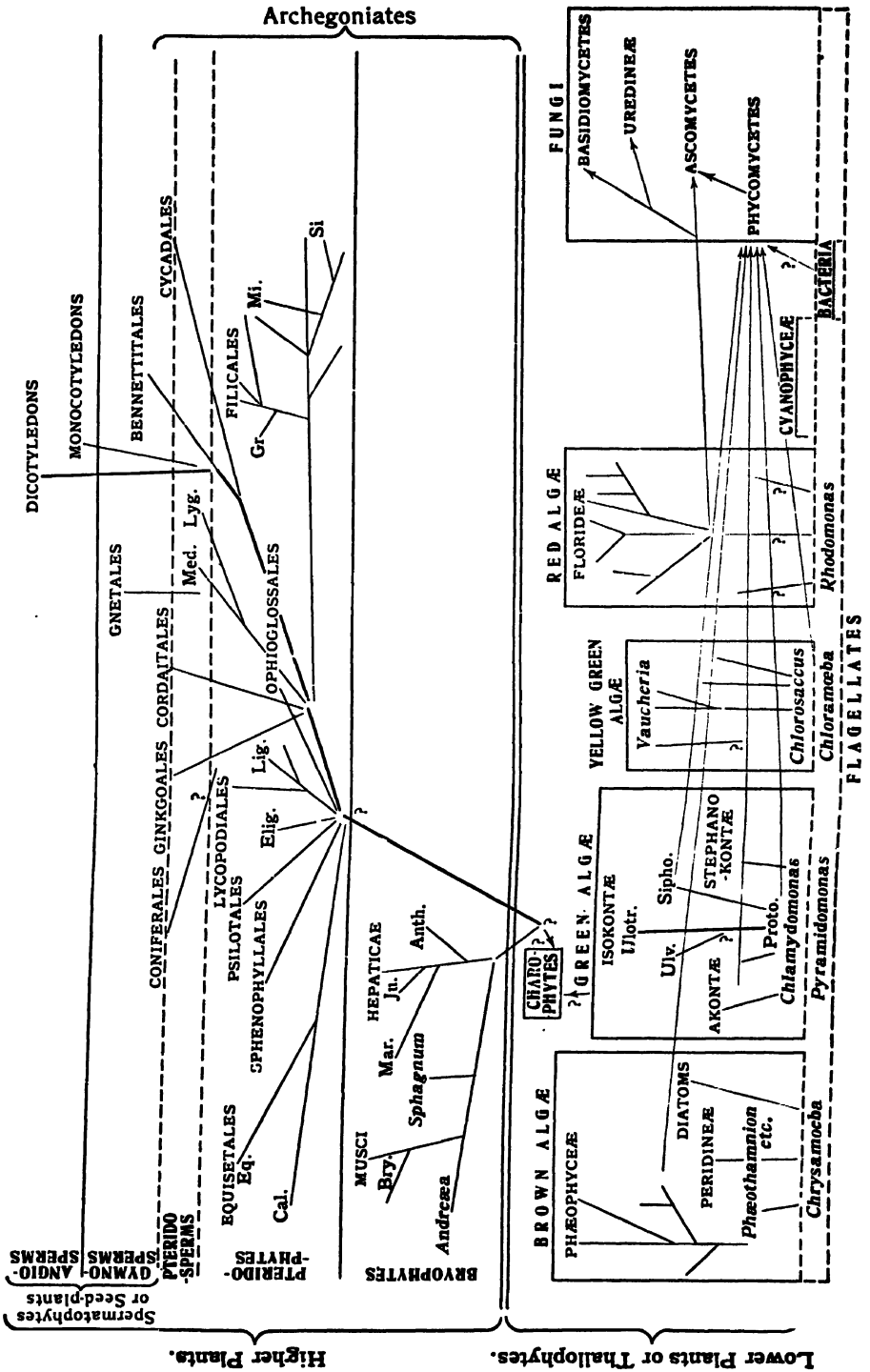
In Plate, fig. 1, and in fig. 205, 1–4*b*, the salient features of several Flagellate types are indicated, especially the variation in number and form of the flagella, and the combination of creeping (amœboid) movement with active swimming. In *Pyramimonas* true chlorophyll is the chief chromatophore pigment, while in *Chloramœba*, *Chrysamœba*, and *Rhodomonas* the chromatophores are, respectively, yellowish green, golden brown, and red, on account of the preponderance of other colouring matters. The figure of the colourless *Dimorpha* illustrates the ingestion of solid food. Evidently many Flagellates display a mixture, in varied proportions, of the characters of both animals and plants. We may regard the principal series of Algæ as so many developments of the vegetable potentialities of such Flagellates.

ALGÆ

1. **Pyramimonas (greatly magnified).**
2. **Chlamydomonas (greatly magnified).**
3. **Volvox.**
4. **Bryopsis.**
5. **Struvea.**
6. **Halimeda.**
7. **Acetabularia.**
8. **Aphanochaete.**
9. **Edogonium.**
10. **Botrydium.**
11. **Micrasterias.**
12. **Sphacelaria.**
13. **Padina.**
14. **Ectocarpus.**
15. **Polysiphonia.**
16. **Delesseria.**
17. **Leveillea.**



ALGÆ



GREEN ALGÆ

ISOKONTÆ.—While the Isokontan section of the Green Algæ is below hardly marked off from the Flagellate alliance, it extends above to a level at which some of the characteristic features of the Higher Plants begin to take shape; it is, however, by no means a simple series of uniform progression along a single line of advance. No phylum, in fact, better illustrates the rise of a few definitely progressive groups from the midst of a mass of tentative lines of advance by what may be figuratively termed a process of trial and error.

ISOKONTÆ PROTOCOCCALES.—The Protococcales comprise a great variety of series, differing from one another chiefly in the methods of aggregation of the cells to form colonies, and to a much slighter extent in the structure of the constituent units. The most primitive genus, *Chlamydomonas*, occupies an important position; for it has a better claim than any other creature to represent the common ancestor of the Isokontæ, and perhaps of green plants in general. Further, for the score of known species, the constancy of cytological characters has been clearly proved by culture under varying conditions. Finally, within the limits of this single genus can be observed the beginnings of all the tendencies which become in higher genera the outstanding features of plants—as opposed to Flagellates.

CHLAMYDOMONAS.—At first sight a typical *Chlamydomonas* (Plate III, fig. 2) does not differ materially from a Flagellate except in the presence of a permanent *cellulose membrane*. But a study of the life-histories of the various species of *Chlamydomonas* reveals important advances upon the Flagellate life-history. Twice- or thrice-repeated division of the cell contents, accompanied in each case by mitosis (see GENERAL BIOLOGY), gives rise to four or eight naked daughter individuals or *zoospores*; these escape in the naked condition, but by growth and secretion of a cell wall soon become vegetative cells once more. In addition, *gametes* are produced, which closely resemble zoospores in appearance and mode of origin; instead, however, of reverting to the vegetative condition, they amalgamate in pairs—nuclear fusion accompanying the union of cytoplasm—to produce a *zygote* which acquires a stout membrane and becomes a resting cell, destined to undergo a period of inactivity, but in return endowed with enhanced powers of resistance to drought and other hostile influences. Later, the zygote “germinates”, the contents dividing to form several zoospores, which behave like those produced by vegetative cells. While most species of *Chlamydomonas* swim about actively in the vegetative stage, coming to rest only during division, a few (for example, *C. Kleinii*) lead an almost sessile existence; in this case a number of cells hang together loosely by their gelatinized cell-walls, either moving about sluggishly in the jelly or dispensing entirely with flagella. *Chlamydomonas* thus displays the rudiments of three or four important characters not found in Flagellates, the most striking of which perhaps is the production of gametes. That sexuality is a character of phylogenetically recent

FLAGELLATES, GREEN ALGÆ AND
YELLOW GREEN ALGÆ

- 1, *Chloramœba heteromorpha*. *o*, oil drops.
 - 2*a*, *Chrysamœba radians*, swimming freely ("Flagellate condition").
 - 2*b*, The same, creeping ("Amœboid condition").
 - 3, *Rhodomonas baltica* (diagrammatic).
 - 4*a*, *Dimorpha radiata*, swimming.
 - 4*b*, The same, creeping and taking in solid food.
 - 5*a*, *Pandorina Morum*.
 - 5*b*, The same: conjugation of gametes.
 - 6, *Hormospora* sp.
 - 7, *Pleurococcus vulgaris*.
 - 8, *Richteriella botryoides*.
 - 9, *Scenedesmus quadricauda*.
 - 10, *Protosiphon botryoides*.
 - 11, *Caulerpa macrodisca*.
 - 12, *Stigeoclonium tenue*. *chr.*, chromatophore; *n.* nucleus;
cv., contractile vacuoles.
- 11 reduced; the rest more or less magnified.
The whole plant is figured, except in 6 and 11.

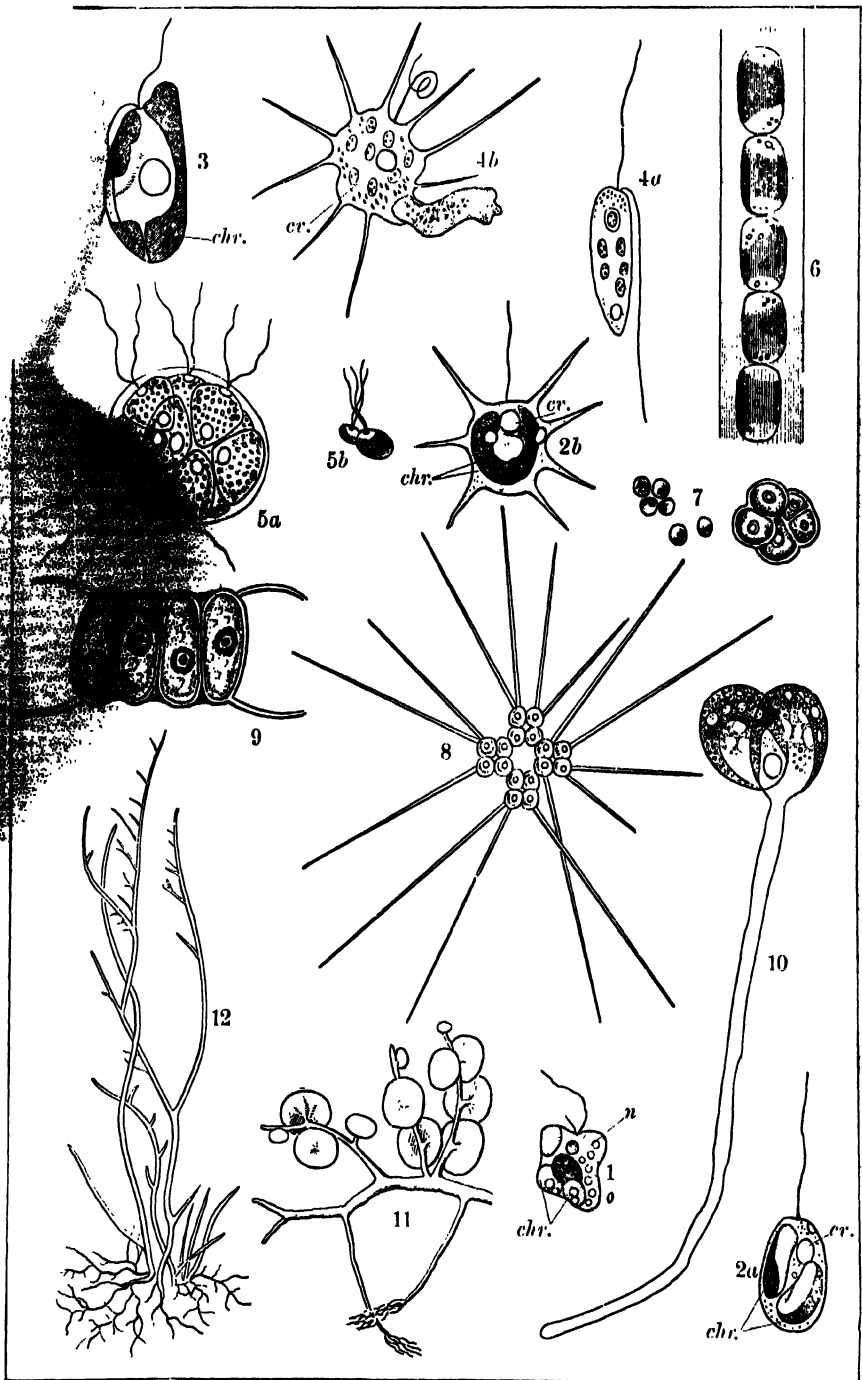


Fig. 205

FLAGELLATES, GREEN ALGÆ AND YELLOW-GREEN ALGÆ

origin in this genus is suggested by the fact that in a number of species the gametes are at first encased in a cellulose membrane just like vegetative individuals; on the other hand, one species at least (*C. Braunii*) has attained to a distinction of sexual germs into larger female and smaller male gametes.

OTHER PROTOCOCCALES.—The bulk of the Protococcales may be regarded as higher developments of the Chlamydomonas type; among them the sessile mode of life is almost universal, while the other tendencies started by Chlamydomonas are followed up to a greater or less extent in different series. A considerable number of genera are unicellular, but the leaning towards aggregation of cells to form colonies is very marked.

One series even remains faithful to the primitive free-swimming manner of life, although its highest member, *Volvox* (Plate, fig. 3), is in other respects an advanced type. *Pleurococcus* (fig. 205, 7), on the other hand, multiplies only by ordinary division, and so carries the sedentary habit to excess. In both *Scenedesmus* (fig. 205, 9) and *Richteriella* (fig. 205, 8) the individual cells differ rather markedly in form from the Chlamydomonas type; but in either case the difference is connected with adaptation to a floating existence; the bristles of *Richteriella* serve for increase of surface, while the crooked shape of *Scenedesmus* prevents the plant from tilting into the vertical position. *Hormospora* (fig. 205, 6) and its allies have a thread-like structure, which marks these forms as the forerunners of the great filamentous ULOTRICHALES group. *Chlorococcum*, outwardly not unlike *Pleurococcus*, differs strikingly in the fact that division of the entire cell never takes place; in old bulky cells, however, the nucleus may divide repeatedly. This "cœnocytic" tendency is elaborated in the large group of the SIPHONALES, the varied types of which all agree in the absence or infrequency of transverse walls. The HYDRODICTYACEÆ (e.g. *Pediastrum*) form a separate cœnocytic series, and yet another variation of this plan of structure is seen in the ENDOSPHÆRACEÆ, which live in the interior of higher plants either as "endophytes"—that is, merely for the sake of shelter—or as actual parasites (*Rhodochytrium*).

SIPHONALES.—The most typical of the SIPHONALES compose the section Siphonæ; in these the plant body is tubular, generally richly branched, and quite devoid of complete cross walls. The simplest form, *Protosiphon* (fig. 205, 10), shows little advance upon *Chlorococcum*, but the majority of Siphonæ have distinct downward-growing "root" (fixing) and upright "shoot" (assimilating) regions. The shoot may be further differentiated, as in *Bryopsis* (Plate, fig. 4) and *Caulerpa* (fig. 205, 11); the numerous species of the latter genus curiously mimic the outward forms of various land plants.

Halimeda (Plate, fig. 6) shows how a fairly complicated and bulky thallus may be produced by the interweaving of originally separate branches, an arrangement which recurs in several groups of Algæ and also among Fungi. *Acetabularia* (Plate, fig. 7) has a main stem bearing separate "whorls" of sterile and fertile branches; all the members of a fertile whorl cohere in the form of a hollow disc. Both *Halimeda* and *Acetabularia* possess a surface coating of lime; this "calcification" is not

uncommon among Algæ, and often serves, as in the present instances, to give strength to an otherwise delicate structure.

In all the Siphonocladæ a certain number of transverse walls occur in the vegetative body; indeed, in the filamentous Cladophoraceæ, of which *Cladophora* is the most familiar, they may be so numerous that each segment contains but two energids. The very elegant *Struvea* (Plate, fig. 5) also belongs to this section.

ULOTRICHALES AND ULVALES.—The thallus of the ULOTRICHALES is generally filamentous, more or less branched, and composed of segments containing single energids. Apart from the primitive *Ulothrix*—which is hardly more advanced than *Hormospora*—and a few aberrant forms, they possess a horizontal branch system from which arise a number of erect shoots (*Stigeoclonium*, fig. 205, 12).

Most of these typical forms, again, can be arranged in two parallel series, in each of which a gradual reduction of the vertical branches takes place. This simplifying of the thallus is connected with the strong tendency of these Algæ to become epiphytes (*Acrochete repens*), harmless endophytes (*Chætonema*), or even partial parasites (*Acrochete parasitica*; *Cephaleuros*, fig. 206, 1). In the larger of these two series (Chætophoraceæ) traces of the erect shoot are often retained in the shape of hairs or bristles. *Aphanochete* (Plate, fig. 8) is especially instructive; for here the hairs may be artificially induced to grow out into upright branches.

The ULVALES, such as the common Green Laver (*Ulva latissima*), have a compact membranous body resembling the "parenchyma", which is the simplest form of adult tissue in the Higher Plants. But a low position is assigned to this group on account of its simple type of reproduction.

REPRODUCTION IN ISOKONTÆ

ASEXUAL REPRODUCTION.—The ordinary reproductive cells of Isokontæ agree in general structure with the zoospores of Chlamydomonas, and like them bear two equal flagella at the anterior end. The asexual germs show little variation. Sometimes spores which have no flagella, but which otherwise resemble zoospores, are formed, as in *Ulothrix*, where numerous intermediate forms connect these "aplanospores" with the zoospores; or cells may be bodily changed into immovable spores (akinetes), an arrangement which recalls the "encystment" of Flagellates.

SEXUAL REPRODUCTION.—While the great majority of Isokontæ are isogamous, there are some notable exceptions.

In *Pandorina* (fig. 205, 5a, 5b) the size of the sexual germs is very variable, and in a given crop of gametes the largest never fuse with one another, but are sought out by smaller ones. Distinct male and female gametes occur also in *Phyllobium* (Endosphæraceæ), in several of the Siphonales, and in *Aphanochæte*.

Volvox has specialized egg-cells and antherozoids (oogamy), and the same is true of *Coleochæte* (Ulotrichales; fig. 206, 2 and 3), the reproduction of which is remarkable in several ways. Here the egg-cell is retained within its mother-cell, the oogonium, and after fertilization the latter

becomes encased in protecting branches. The fertilized egg (oospore), on germinating after a period of rest, produces a small but compact mass of green cells. Each of the latter then gives rise to zoospores, which are the starting points of new Coleochaete plants. One is tempted to compare this many-celled body derived from the oospore to the spore case of a Liverwort like *Riccia* (see below, p. 50).

STEPHANOKONTÆ AND AKONTÆ.—Besides the great group of the Isokontæ, two minor divisions of Green Algæ may be recognized.

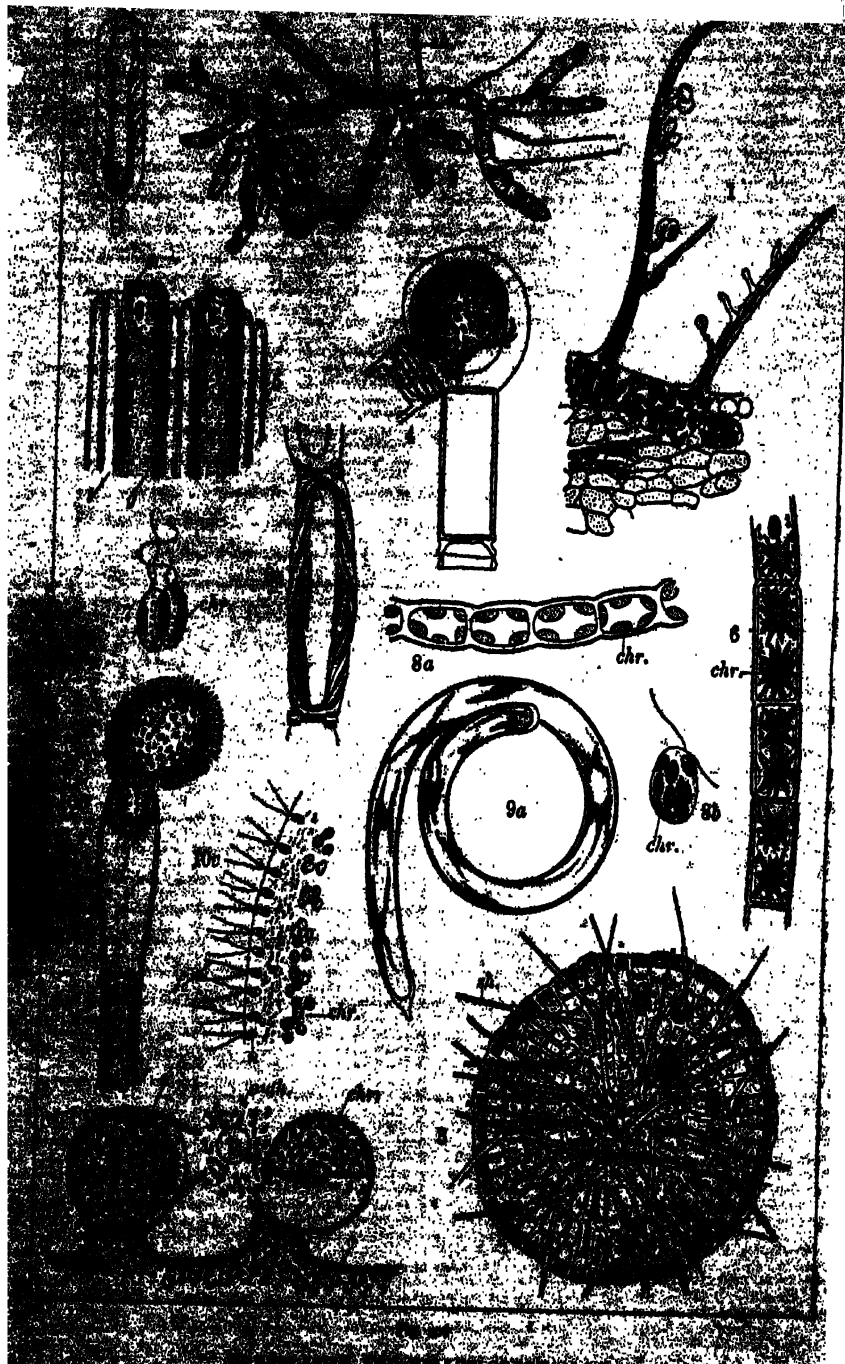
Eedogonium (Plate, fig. 9; fig. 206, 4) is the type of the STEPHANOKONTÆ; the zoospores and male gametes have a wreath of flagella around the apex. In the filamentous thallus growth is limited to certain cells and is of a very special kind. All the known forms are oogamous. The AKONTÆ have no motile cells at all. Sexual union takes place by means of a so-called "fertilization tube"; this is a short-lived structure in the Desmiales but persistent in the Zygnemales, and these two sections of the division differ in other respects. They agree in their extraordinarily symmetrical structure (see the Desmid *Micrasterias*, Plate, fig. 11; and *Zygnema*, fig. 206, 6). Akontæ are usually simple in outward form; but specialized types are not wanting, witness the Desmid *Oocardium* (fig. 206, 5), the cells of which live in calcareous tubes somewhat like coral polyps.

YELLOW-GREEN ALGÆ (HETEROKONTÆ)

A very interesting parallel to the Green Algæ is furnished by the Yellow-green Algæ, the motile germs of which share the general structure of the Flagellate *Chloramæba* (namely, disc-shaped, yellow-green chromatophores; no pyrenoids; oil in place of starch; two flagella, differing in length or direction or in both particulars).

Chlorosaccus consists of a number of yellow-green individuals embedded in a jellylike substance. A particular cell-wall is distinguishable around each energid, but this membrane is well developed only on the outer face of each cell, and is sometimes altogether wanting on the inner side. The zoospores arise by longitudinal division and have two unequal flagella (fig. 206, 7). The existence of a form like *Chlorosaccus* suggests that the yellow-green Flagellates may have given rise to Algæ built upon similar lines; and it is of great interest to find that many of the developments which have been traced among the Green Algæ are paralleled by yellow-green plants. Thus *Tribonema* (fig. 206, 8a, b, c) roughly corresponds to *Ulothrix*, and the cœnocytic *Botrydium* is superficially just like *Protosiphon*, while the parasitic *Phyllosiphon* is perhaps the counterpart of *Phyllobium*.

The genus *Vaucheria* agrees in many respects with the Yellow-green Algæ, although it has generally been placed among Siphonææ, because of its tubular body devoid of cross walls; its true position, however, is quite uncertain. *Vaucheria* surpasses even *Ulothrix* in the variety of its reproductive processes. The zoospores are very peculiar (fig. 206, 10b, c), and the gametes are of the highest type (fig. 206, 10a).



BROWN ALGÆ

The Brown Algæ comprise several distinct phyla, which agree with one another chiefly in the association of brown colouring matter with the chlorophyll, and in the replacement of starch by other reserve materials such as oil.

PERIDINEÆ AND DIATOMS.—The PERIDINEÆ (Dinoflagellata) and DIATOMS (Bacillariales) are all small and unicellular, but nevertheless specialized in many ways; their two-valved cell membranes in particular have a remarkably complicated structure. All the Peridineæ, and many Diatoms, are plankton organisms. The most conspicuous features of these are connected with the exposure of a large surface (*Ceratium*, fig. 207, 1; *Ornithocercus*, fig. 207, 2; *Syndetocystis*, fig. 207, 4). Those benthos diatoms that are unattached can glide about slowly; but the movements are not due to flagella, which are unknown in this group, whereas they are always present in Dinoflagellates. Other benthos forms are fixed, and, in many of these, numerous cells remain connected and form a colony (p. 17). A few simple flagellated brown plants with two-valved membranes are known (e.g. *Exuviella*), and the existence of these perhaps indicates a common origin for Peridineæ and Diatoms. But until the reproductive processes are better known it seems advisable to regard the several unicellular brown groups as isolated phyla.

CHRYSMONADINA AND ALLIED FORMS.—Many undoubtedly primitive brown forms (*Phæocystis*, fig. 207, 8a, b, c; *Phæothamnion*, fig. 207, 9, &c.), the analogues of various Protococcales and Heterokontæ, are already known; they seem to link up Chrysamœba and other undoubted Flagellates (Chrysmonadina) with the higher brown plants (Phæophyceæ), although the actual connections are as yet uncertain.

PHÆOPHYCÆ OR BROWN SEaweEDS.—The Phæophycæ, like the Isokontæ, comprise, in the first place, a mass of relatively simple types, and, secondly, a few higher groups rising above the ruck. But in the present case the starting-points of the different series are by no means clear, and the whole phylum begins at a rather higher level; for the Ectocarpaceæ—which correspond to the Protococcales—are all filamentous, and in the higher series very large and elaborate plant-bodies are found. The simplest genus, *Ectocarpus* (Plate, fig. 14), stands at a level corresponding to that of *Stigeoclonium* among Ulotrichales. The differences between the various species as regards their manner of growth are particularly interesting. In some cases every cell of the plant is capable of continued growth and division; in others special growing cells are set apart, so that division is restricted, generally to the base or middle of a branch (intercalary growth), less often to the free end (apical growth). The higher groups of Brown Seaweeds always have this restricted mode of growth, and each family adheres strictly either to the apical (Sphacelariaceæ, Dictyotaceæ, Fucaceæ) or to the intercalary (Cutleriaceæ, Laminariaceæ) variety. A passing reference may be made to a series—evidently a brown “copy” of the Chætophoraceæ—in which the *Ectocarpus* type becomes reduced to a flat epiphytic (*Ascocyclus*, fig. 207, 10), or parasitic (*Phæostruma*) structure.

BROWN ALGÆ

- 1, *Ceratium macroceras*. *f*, One flagellum. Only the base of the longest spine is included in the figure.
 - 2, *Ornithocercus magnificus*: side view. *b*, Vertical or balancing wing; *p*, double parachute; *f*, one flagellum.
 - 3, *Cyclotella radiosa*. Besides the cells, only the firmer connecting strands that traverse the gelatinous ground substance of the colony are figured.
 - 4, *Syndetocystis barbadensis*. In this fossil diatom the arrangement for holding together the members of the chain is a very perfect one.
 - 5, *Gyrosigma attenuatum*.
 - 6*a*, *Gomphonema geminatum*; surface view of one valve ("valve view").
 - 6*b*, The same seen from the side ("girdle-view").
 - 7, *Encyonema cæspitosum*. *c*, Cells; *j*, encasing jelly.
 - 8*a*, *Phæocystis Poucheti*. *g*, Group of cells; *j*, jelly.
 - 8*b*, A small portion of the colony. *chr*, Chromatophores; *l*, leucosine body.
 - 8*c*, Zoospore; the two flagella are attached to one side and point in different directions.
 - 9, *Phæothamnion confervicolum*; zoopores escaping.
 - 10, *Ascocyclus secundus*; a half-grown disc.
 - 11, *Macrocyctis pyrifera*. Tip of a shoot. The terminal region is compact; the growing zone lies at *g*. Farther back the thallus splits up into a stemlike portion, *s*, and leaf-like segments, *l*, each with a float, *f*.
 - 12, *Halopteris filicina*. *a*, Apical cells.
 - 13, Diagram of an apical cell of *Fucus*, showing the formation of walls nearly parallel to various faces.
 - 14, *Sargassum*. *st.*, Part of a stemlike shoot of unlimited growth; *l*, leaf-like branches of limited growth; *f*, floats; *r*, reproductive branches.
 - 15, *Battersia mirabilis*. *u.s.*, Unilocular sporangia; *r.p.*, remains of previous sporangia.
 - 16, *Chorda filum*; zoospores.
 - 17, *Ectocarpus siliculosus*; gametes escaping from a plurilocular sporangium, *p.s.*
- Figs. 11-14 reduced; the rest magnified. Figs. 1-3, 5, 6*a*, 6*b*, 8*a*, 9, and 10 show entire plants or colonies; the rest, parts of plants or of colonies.



Fig. 807

BROWN ALGÆ

Halopteris (fig. 207, 12) shows the very conspicuous apical cell characteristic of the Sphacelariaceæ, while the somewhat isolated Dictyotaceæ must be mentioned if only because this family includes the beautiful iridescent *Dictyota* (fig. 207, 13). The Laminariaceæ and Fucaceæ are at once distinguished by the presence of the brown, gelatinous, mucous substance, the agar, which is secreted by the cells of the plant body. The Laminariaceæ (fig. 207, 14) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Fucaceæ (fig. 207, 15) are also common, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 16) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 17) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 18) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 19) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 20) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 21) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 22) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 23) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 24) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 25) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 26) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 27) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 28) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 29) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 30) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 31) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 32) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 33) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 34) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 35) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 36) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 37) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 38) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 39) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 40) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 41) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 42) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 43) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 44) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 45) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 46) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 47) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 48) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 49) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 50) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 51) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 52) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 53) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 54) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 55) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 56) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 57) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 58) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 59) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 60) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 61) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 62) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 63) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 64) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 65) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 66) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 67) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 68) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 69) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 70) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 71) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 72) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 73) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 74) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 75) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 76) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 77) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 78) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 79) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 80) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 81) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 82) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 83) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 84) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 85) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 86) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 87) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 88) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 89) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 90) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 91) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 92) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 93) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 94) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 95) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 96) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 97) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 98) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Sphacelariaceæ (fig. 207, 99) are the most common of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast. The Dictyotaceæ (fig. 207, 100) are the most beautiful of the Brown Algae, and are found growing on the rocks and in the shallow water of the coast.

REPRODUCTION IN PHÆOPHYCEÆ.—*Ectocarpus* bears two kinds of germ-producing organs. A *unilocular sporangium* (see *Battersia*, fig. 207, 15) is an enlarged cell of special form; its contents give rise to numerous asexual zoospores, each with two flagella springing from one side and pointing in opposite directions (see *Chorda*, fig. 207, 16). A *plurilocular sporangium* (fig. 207, 17) is divided into a large number of compartments, in each of which a gamete, resembling an asexual swarmer, is formed. The sexual zoospores of *Ectocarpus siliculosus* are all in appearance uniform, but vary in behaviour; in every crop a few are relatively sluggish and play the part of female gametes. Male and female germs differing from one another at least in size are found in certain *Ectocarpaceæ* and *Sphacelariaceæ* and in the *Cutleriaceæ*. Oogamy is characteristic of *Dictyotaceæ* and *Fucaceæ*. The last-named group has its sexual organs sunk in cavities (conceptacles), and is further remarkable for the absence of asexual reproduction, while *Laminariaceæ*, on the contrary, possess no sexual germs.

RED ALGÆ

The Red Algæ, like the Brown, are a mixed assemblage. Among the great variety of Flagellate types red forms are not lacking, (e.g. *Rhodomonas*, p. 26), and a few simple plants are known (*Porphyridium*, &c.) which seem to be red duplicates of certain *Protococcales*; but as the true Red Seaweeds (*RHODOPHYCEÆ* or *FLORIDEÆ*) which form the bulk of the Red alliance have no motile cells, direct evidence of Flagellate ancestry is not available.

As a matter of fact the *Rhodophyceæ* have no obvious affinity with any other phylum (see, however, below, p. 43); from a general standpoint they are interesting mainly on account of their remarkable reproductive processes.

The plant body of the *Florideæ* displays extraordinary diversity of shape (see Plate, figs. 15, 16; 17), but consists almost without exception of

REPRODUCTION IN RED SEaweEDS

- 1, *Callithamnion corymbosum*; *t*, tetraspores.
 - 2, *Polysiphonia rhunensis*; *a.b.*, special antheridial branch.
 - 3*a*, *Nemalion*, antheridia and carpogonium.
 - 3*b*, The same: carpospores.
 - 4*a*, *Dermonema* sp.; carpogonial branch (*c.b.*).
 - 4*b*, The same: sporogenous filaments (*s.f.*).
 - 5, *Galaxaura fragilis*, cystocarp resembling the ascus-fruit of an Ascomycete fungus; *s.f.* sporogenous filaments.
 - 6*a*, 6*b*, *Dudresnaya purpurifera*; *a.c.*, auxiliary cells.
 - 7, *Corallina virgata*; *co.*, conceptacle or chamber containing several carpogonia; *n*, nursing cells.
 - 8, *Chylocladia* sp.; *n*, nursing cells. *a*, antheridium; *s*, spermatium; *c*, carpogonium; *t*, trichogyne.
- All figs. magnified. Figs. 4-8 are from sections.

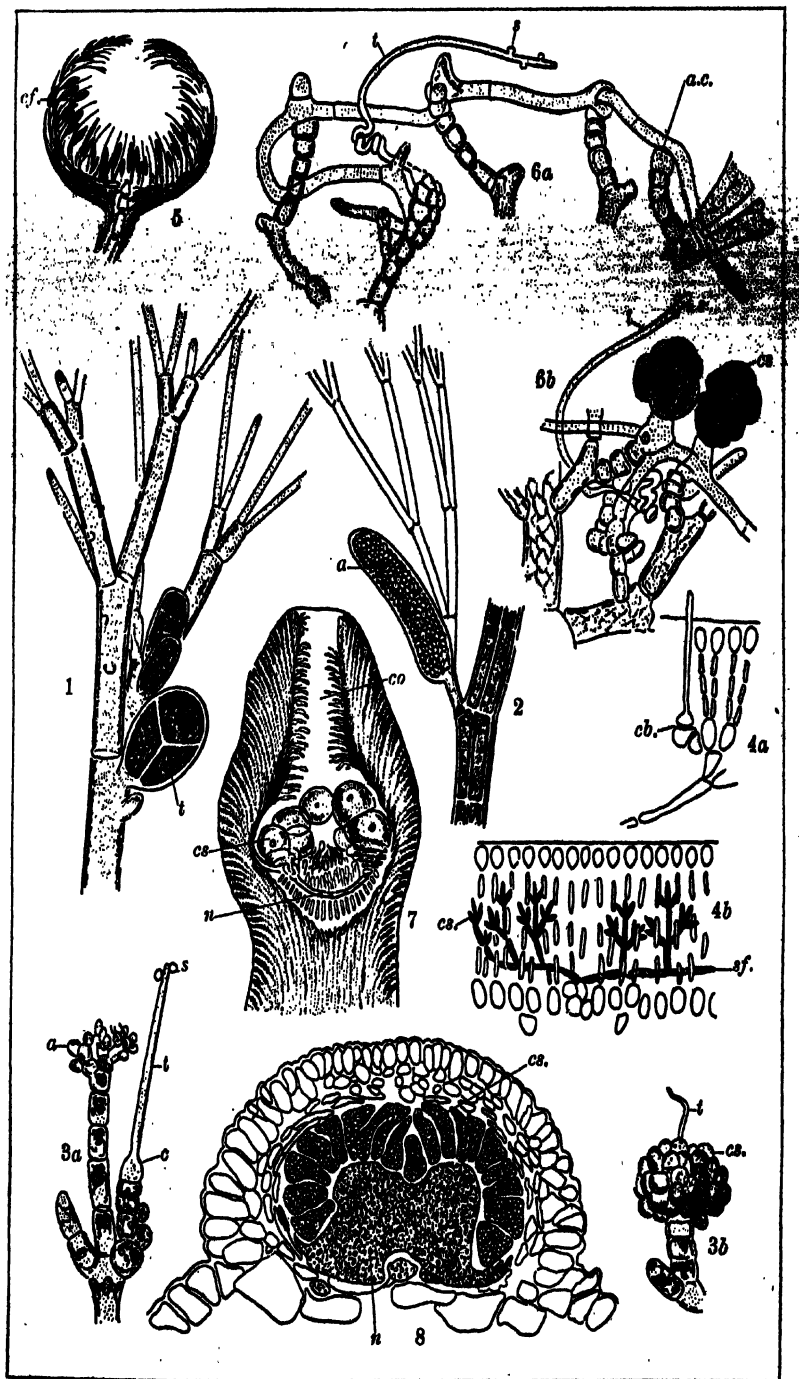


Fig. 208

REPRODUCTION IN RED SEaweEDS

a system of richly branched filaments, which are usually interwoven or otherwise combined to some extent.

REPRODUCTION IN RED SEAWEEDS.—Asexual spores arise in groups of four (tetraspores) within special mother-cells (tetrasporangia; fig. 208, 1). There are very distinct male and female gametes, namely, spermatia, produced in antheridia (fig. 208, 2 and 3a), and egg-cells, enclosed in oogonia (carpogonia). Each carpogonium terminates a special branch, and consists of a flask-like base enclosing the egg-cell and a slender neck (trichogyne), which serves as a trap for spermatia (fig. 208, 3a, 4a, 6a). The most striking character of the Red Seaweeds is the behaviour of the fertilized egg; this is not a resting cell but germinates at once, giving rise in the simplest case to a number of filaments (short in *Nemalion*, fig. 208, 3b; long and branched in *Dermoneia*, fig. 208, 4b), from each segment of which a single spore (carpospore) is liberated. In other cases the tubes proceeding from the egg do not themselves directly produce carpospores, but wander for considerable distances through the thallus, fusing with certain cells marked off by their rich store of food materials; from these "auxiliary cells" the actual spore-producing filaments then arise (*Dudresnaya*, fig. 208, 6a, b). The spore-masses generally become encased in special sterile branches, and often regular "fruits" (cystocarps) are formed in this way (*Galaxaura*, fig. 208, 5).

A full understanding of the reproduction in Rhodophyceæ is not yet possible, if only because the complete life-history has not been followed up in any of the marine species. Quite recently cytological evidence, based upon a study of the nuclear divisions (see GENERAL BIOLOGY, chap. iii), has been brought forward from which it appears that in *Polysiphonia violacea* the carpospores on germination give rise to purely asexual (tetraspore-forming) plants, while the tetraspores produce either male (spermatium-forming) or female (carpogonium-bearing) individuals. Thus the asexual phase of the life-history starts with the fertilized egg and comprises first a stage of dependence upon the female plant, and secondly a free-living stage, the neuter individual. The sexual phase begins with the tetraspore and ends with the spermatium or egg. The male, female, and neuter plants are, however, outwardly all exactly alike. It remains to be seen how far this scheme applies to other Florideæ.

The "auxiliary cells" must be regarded as centres of food supply for the developing carpospores. In certain advanced members of the phylum large "nursing" structures are formed by the fusion of auxiliary cells with one another (*Corallina*, fig. 208, 7) or with adjacent unspecialized cells (*Chylocladia*, fig. 208, 8).

CHAPTER VII

FUNGI AND OTHER ABERRANT
THALLOPHYTES

Although the Yellow-green, Brown, and Red Algæ deviate considerably from the central Green Series, all four phyla nevertheless progress in the same general direction, though not along identical paths. But the Fungi, in their dependent mode of nutrition, follow a bent which is utterly opposed to the tendency of coloured plants; on this account they are here regarded as aberrant in comparison with all the phyla previously discussed. At the same time it must be clearly understood that the Fungi do not form a natural tribe, but that, on the contrary, they are a motley company to which the several groups of Algæ have contributed at various levels of evolution and probably under the influence of a variety of factors. In an ideal arrangement the different families of Fungi would be annexed to the algal series of which they are colourless offshoots; but in the present state of our knowledge it is inadvisable seriously to disturb the conventional classification.

THE MYCELIUM.—The plant body in the Fungi is almost always a MYCELIUM, that is, a greatly branched system of delicate filaments or HYPHÆ. The prevalence of this kind of thallus is no doubt connected with the fact that most Fungi grow in the dead or living substance of other plants, that is, in a medium which is solid and on the whole not easily disintegrated.

A certain number of Fungi are unicellular or have a very feebly developed mycelium; some of these are derived from Protococcales (thus, *Rhodochytrium* from Endosphaeraceæ; *Prototheca* from the Pleurococcus series) or from even lower groups (thus some of the Chytridineæ), while others are certainly reduced from the mycelium condition owing to their return to life in a liquid medium (thus the 'Yeast-forms' of many Fungi and perhaps also the Genuine Yeasts or Saccharomycetes, fig. 209 *bis*, 8*a* and *b*). On the other hand, Higher Fungi, by interweaving of hyphæ often form large and solid structures, sometimes for vegetative purposes, but more often in connection with reproduction.

CLASSIFICATION OF FUNGI

It is customary to subdivide the Fungi into several great classes (I-V) with reference mainly to two characters—to wit, the nature of the principal reproductive process and the presence or absence of cross-walls in the mycelium.

The lower filamentous Fungi or SIPHONOMYCETES (II) have a mycelium devoid of transverse septa and recalling the thallus of a simple Siphonous Alga or of Vaucheria; their asexual germs are zoospores or aplanospores, formed within sporangia, or less often CONIDIA, that is spores cut off from the ends of more or less specialized hyphæ. Sexual organs are always

Basidiomycetes nor Zygomycetes possess a typical sexual process; but recent cytological work has made it very probable that the latter group is derived from actual forms, and certain nuclear fusions in Basidiomycetes suggest a similar origin for them. "Accessory" reproductive structures, which often take the form of sporidia, occur in each section of the Mycomycetes.

SAPROPHYTES. Plick has given an interesting review, from the oecological standpoint, of the different types of spore found among saprophytic fungi. He points out that the more readily digestible portions of dead plants (sugars, starch, inuline, glycogen, fat, &c.) are exploited by the Lower Fungi, together with bacteria and animal scavengers. The unseptate condition of the mycelium allows of very active internal transport of materials by means of currents in the living substance, which are here extraordinarily strong and swift. The production of zoospores by the aquatic forms (Oomycetes) is an advantage in so far as these swimming germs can readily respond to chemical stimuli, and can in this way be guided to the centres from which attractive substances are diffusing. The terrestrial Zygomycetes typically—as in the case of *Mucor*—produce in their sporangia sticky spores adapted for dispersal by herbivorous animals, which swallow them with their green food. But the spore type varies considerably in this group. On the one hand, some genera (e.g. *Thamnidium* and *Chaetocladium*) very clearly show the transition from the adhesive sporangium-spore to the wind-blown conidium; while on the other, *Pilobolus* (Plate, fig. 4) forcibly squirts its entire sporangium to a distance. In all the Phycomycetes the sexually produced spores (fig. 209, 3) serve to tide over unfavourable periods (resting spores).

The Higher Fungi are, with very few exceptions (such as the Ascomycete *Mitrella*), terrestrial; in comparison with the Phycomycetes their mycelia are on the whole long-lived and slow-growing.

The Ascomycetes attack moderately digestible plant debris, such as dead leaves, dead herbaceous shoots, bark, &c., and the like. The typical ascus is an apparatus for the ejection of adhesive spores. In forms like

FUNGI AND PARASITIC FUNGI

Peziza or the *Morels* (*Helvella*, fig. 209, 4, *Helvella*), where the layer of asci lies freely exposed, the entire contents of an ascus are thrown out together. When the hymenium lines a narrow-mouthed receptacle or *perithecium* (cf. *Claviceps* and *Cordyceps* among parasitic genera), the liberation of the spores, if explosive at all, is intermittent; but often in this type the contents of an ascus are squeezed out gently and gradually. Ordinarily each ascus of a fructification bursts independently, but in the bulky forms like *Helvella* and *Peziza* a simultaneous discharge of many asci takes place in dry air; this "puffing"—which is sometimes so vigorous as to cause an audible hissing sound—is evidently an adaptation to wind dispersal, and in those cases in which the action is intensified by shaking, perhaps also to transport by animals.

The Basidiomycetes have a curious method of germ dispersal. The basidiospores, which are extraordinarily light, are cut off from the ends of slender stalks in such a way that they drop singly from the hymenium into an adjacent space. Hence they are carried away by ascending air currents of the feeblest kind, from which they are readily deposited on the *upper* surfaces of surrounding objects; what is perhaps most remarkable is that these currents are set up, in the immediate neighbourhood of the fruit body, by the heating effect of its own very active respiration. Here again the type of spore distribution is evidently related to the vegetative life of the fungus; for the Basidiomycetes are the special destroyers of woody tissues, the most resistant of vegetable remains. The latter decompose on a large scale only in the forest, and minute air currents are the best agents of dispersal in these circumstances. In the Gastromycetes, a group comprising a number of distinct families of Basidiomycetes, with complicated fruit bodies which remain *closed* until the spores are ripe, different arrangements are found. Thus several genera have fleshy underground fruits (recalling the Truffles, which are, however, Ascomycetes), the scent and flavour of which are attractive to mammals that aid in dispersing the spores; while the gaudy colouring and abominable stench of the Phallaceæ and Clathraceæ (Plate, fig. 8) secure dispersal of the spores by carrion-flies. The Puffballs (Lycoperdaceæ), on the other hand, are adapted for wind distribution (Plate, fig. 5); the spore-mass of a large fruit, well lightened by a network of hygroscopic threads, doles out germs to the winds for months together. *Sphaerobolus* (Plate, fig. 10), finally, which shoots away the whole spore-producing mass when ripe, from the rest of the fruit, follows the principle already illustrated by *Pilobolus* and by many Ascomycetes, although in the Gastromycete the apparatus is more elaborate. :

PARASITES.—The descriptions which have been given above of a few prominent spore types among the saprophytic Fungi apply also to many parasitic species. But among parasites greater variety in the details of the reproductive processes is to be expected. The Ergot of Rye (*Claviceps purpurea*, fig. 210) produces in the early stages of its life-history conidia for rapid dispersal. These are carried to other Rye flowers by insects which feed upon the sweet slimy liquid (honeydew) which forms in infected ears. A diseased Rye flower ultimately develops into a hard *sclerotium*

This is the resting-stage of the fungus, and consists of closely interwoven tough and thick-walled hyphæ. It takes the place of the proper fruit, and is, in fact, a "mummified" grain. After a long resting period ascus-fruits arise from the sclerotium; the ascus-spores are set free from these explosively, and some of them reach the flowers of Rye or of other susceptible grasses. Similar sclerotia are formed by *Cordyceps* (Plate, fig. 3),

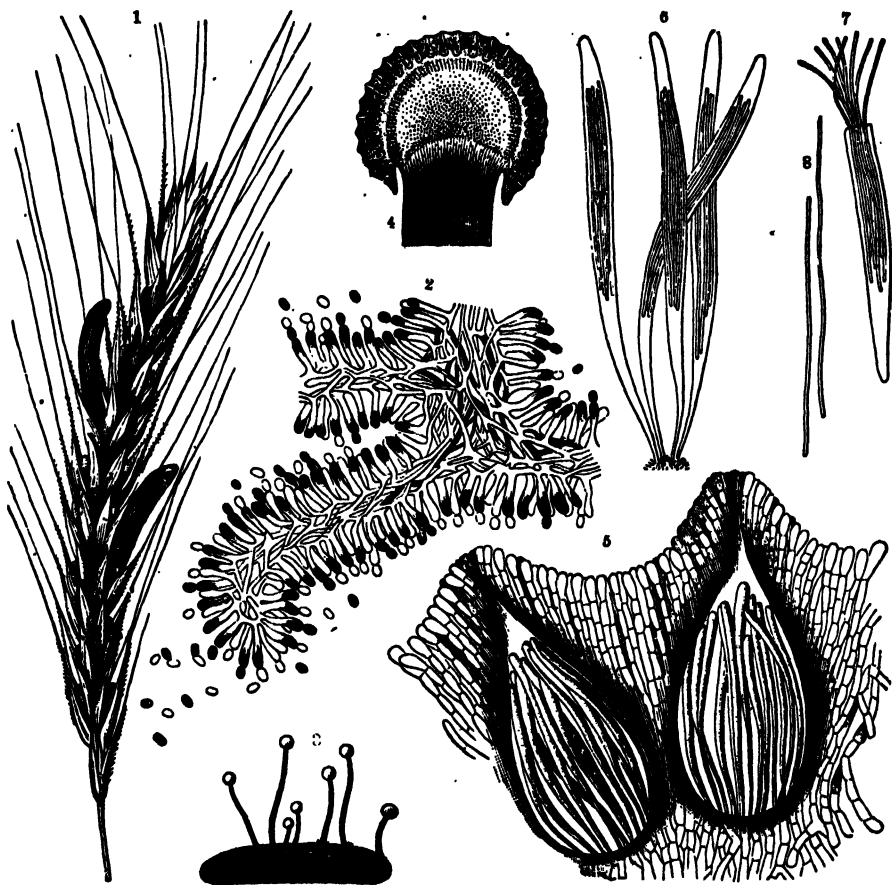


Fig. 210.—The Ergot of Rye, *Claviceps purpurea*

1, Ear of Rye showing two sclerotia of the Fungus. 2, Conidia arising from the mycelium which develops around the ovary. 3, Stalked fruit-bodies arising from the sclerotium. 4, Longitudinal section through the head of a fruit-body showing the perithecia at the edge. 5, Vertical section through two perithecia showing the asci. 6, Asci. 7, Ascus liberating its filamentous spores. 8, Filamentous spores. 1, 3, nat. size; 2, $\times 200$; 4, $\times 40$; 5, $\times 50$; 6 and 7, $\times 700$; 8, $\times 750$. (Partly after Tulasne.)

which mummifies the bodies of insects or of their larvæ, and by the *Sclerotinias*, which in other respects are not unlike *Pezizas*. The conidia of *Sclerotinia Vaccinii* (the fungus producing "white" Cowberries) are carried to the flowers by pollinating insects, attracted in this case, by the pleasant scent of the spores. Many similar instances of special arrangements could be mentioned; most often, however, the active spreading of parasitic fungi is carried on by wind-borne spores which are usually conidia.

FUNGI

1. Chytridium.
2. Albugo.
3. Cordiceps.
 - a. Head.
 - b. Perithecia (magnified).
4. Pilobolus.
5. Geaster.
6. Hydnum.
7. Marasmius.
8. Clathrus.
9. Ustilago.
10. Sphaerobolus.
11. Gymnosporangium.
12. Peziza.



PHYLOGENY OF FUNGI

It was pointed out above that the very close relationships of the different families of *Chytridiaceae* to the Algae.

The ARCHIMYCETES are unicellular, or have a single cell in some cases appears to be a mere appendage to the host. They comprise, in the first place, the *Chytridiaceae* (in the wide sense), tiny Fungi very often parasitic upon freshwater... (fig. 1), but in a number of cases upon land-plants. The germs are always motile. Several genera of uncertain position (*Ascoidea*, *Dipodascus*) may be included here for the time being; they certainly have little in common with the Ascomycetes, the group to which they are generally attached. The affinities of the Smuts (*Ustilagineae*, Plate, fig. 9), remarkable for their dark-coloured resting-spores (chlamydospores) are likewise doubtful; it is very possible that they represent an offshoot of the Chytridine series which has successfully practised parasitism upon higher land-plants. Archimycetes are probably derived from Algae of the rank of *Protococcales*, or in part direct from the Flagellates.

The SIPHONOMYCETES, comprising the two sections of Oomycetes (e.g. *Albugo*, Plate, fig. 2) and Zygomycetes (e.g. *Pilobolus*, Plate, fig. 4), have a well-developed mycelium typically quite devoid of septa. It is very improbable that all the forms contained in this group are descended from Siphonous Algae. The sexual process of the Zygomycetes recalls conjugation in Zygnemales, and one of the Entomophthorineae, *Basidiobolus*, is indeed actually placed, by Lotsy, in the Akontae. In various Oomycetes (especially Peronosporae, see fig. 209, 1 a-l) the gradual replacement of zoospores by aplanospores, and of the latter by conidia, is well shown. Motile (male) gametes occur only in *Monoblepharis* and *Myrioblepharis*; in the rest of the Oomycetes, and in Zygomycetes, union takes place through a fertilization- or conjugation-tube (fig. 209, 2a, 3).

The class ASCOMYCETES, even when freed from all alien forms, is still made up of two sets of families which probably have no real affinity with one another. Genera like *Sphaerotheca* or *Pyronema*, in which entire neighbouring cells conjugate through a tube, are presumably related to the Siphonomycetes. Types like *Polystigma* and the *Laboulbeniaceae* (fig. 209, 5a and 5b), with spermatia and "trichogynes", have no evident parallel except among the Red Seaweeds.

Recent work on the cytology of the UREDINEAE has made it very probable that this group also formerly possessed the Red Seaweed form of reproduction. The BASIDIOMYCETES have always been regarded as close allies of the Rusts; and while it is unlikely that the existing Florideae are the ancestors of any Ascomycetes, Rusts, or Basidiomycetes, the bulk of the Higher Fungi and the Red Seaweeds may reasonably be held to have had a common origin. When it is remembered that colourless parasitic species occur in very diverse families of Algae (viz. *Polytoma* in the Volvox series, *Rhodochytrium* in Endosphaeraceae, *Notheia* in

Phæophyceæ, *Harveyella* in Florideæ), it seems not impossible that the ranks of the Fungi (as ordinarily understood) may have been recruited from all the principal coloured phyla.

FUNGI IMPERFECTI AND LICHENS

A very large number of Fungi with septate mycelia are provisionally classed as "Fungi imperfecti", because asci or basidia belonging to them have not been observed. Most of them are probably stages in the life-history of Ascomycetes.

It has already been explained (Vol. III, p. 168) that a Lichen is not an independent being, but a co-operative union of a Fungus with an Alga (or with one of the Cyanophyceæ).

BACTERIA AND BLUE-GREEN PLANTS (CYANOPHYCEÆ)

The BACTERIA, like the Fungi, are for the most part colourless saprophytes or parasites. They differ in important respects from most other plants. The BLUE-GREEN PLANTS (Cyanophyceæ) seem to be their nearest living relatives. A typical nucleus has not been detected in any member of either phylum; gametes are also unknown, and although colouring matter for photosynthesis is present in the Blue-green Plants, actual chromatophores have not been certainly identified. Such negative characters are of doubtful value for classification; but the physiological features of Bacteria are perhaps more instructive. Ordinary coloured plants all directly or indirectly owe their supply of nitrogen to the activity of Bacteria. For the "putrefactive" Bacteria break down the proteids of dead organisms; the "nitrogen-fixers" (*Clostridium pasteurianum*; *Rhizobium* spp.) convert the free nitrogen of the air into organic compounds; and the "nitrifiers" oxidize ammonia to nitrites or nitrites to nitrates. By the combined action of these different microbes on land and in the sea the supply of nitrates required by green plants is continually replenished. The nitrogen-fixing Bacteria demand a supply of carbon in the form of grape-sugar (glucose), but the "nitrifiers" assimilate carbon dioxide with the help of chemical energy derived from the nitrogen oxidation.

It is significant that a number of Bacteria require a range of temperature which at the present day occurs naturally only in the hot springs and fumaroles in which they are found; some of the Cyanophyceæ also lead a similar heat-loving life. Certain other Bacteria stand alone among plants in the fact that they thrive only in the *absence* of free oxygen (anaërobic life), while others again derive their vital energy from substances, such as sulphuretted hydrogen, which are very poisonous to ordinary organisms. The first inhabitants of the earth evidently must have been strictly prototrophic (p. 26). In addition, they were probably called upon to withstand poisonous vapours, floods of boiling water, long periods of darkness, and many other hostile influences. From what we know about the physiology of the Bacteria it seems not unreasonable to look among them for the most primitive forms of life. Lotsy has

recently pointed out that the Sulphur-Bacteria assimilate with a minimum expenditure of energy; and he suggests that near submarine solfataras (as in the Bay of Naples) the conditions perhaps approximate to those under which spontaneous generation of living substance from dead matter might be expected to take place.

Wherever virgin soil is exposed at the present time by any means, as on the retreat of glaciers, or after catastrophes like the convulsion which destroyed all life on the island of Krakatau in the year 1883, the first plants to gain a footing are Cyanophyceæ and Bacteria. Altogether there seems no doubt that, œcologically at any rate, some classes of Bacteria possess many of the qualities of primitive beings. On the other hand, they approach the Flagellates in several respects. Many species have been shown to possess flagella, and assimilation pigments occur in a few cases; but a great many Bacteria are saprophytes and parasites, and it is possible that this alliance also is made up of several groups of distinct origin.

SLIME-FUNGI

The Myxomycetes, Mycetozoa, or Slime-Fungi, are really *animals* allied to the well-known *Amœba*. The notion that a relationship exists between these organisms and the Fungi is largely based upon the superficial resemblance of their spore-masses to "miniature Puff-balls". As there is good reason for believing that the *Amœba* type of animal is derived from swimming flagellated ancestors, it is interesting to note that a flagellated stage occurs in the life of every Myxomycete.

STONEWORKS OR CHAROPHYTA

The last of our aberrant groups is that of the STONEWORKS or Charophyta. These curious plants have a green thallus, built on filamentous lines, which shows extraordinary regularity in its branching and in certain other features. Their sexual organs are more complicated than those of any Alga, but at the same time do not resemble the gamete-producing structures of the Higher Plants. The antherozoids of the Stoneworts, however, are exactly like those of the Bryophyta, a fact which suggests that the former group is either a separate offshoot from the ancestral stock of the Higher Plants or a degraded branch of the Bryophytes.

A word must now be said about fossil Thallophytes, while it will also be convenient at this stage to review the Lower Plants from the point of view of their usefulness to man.

FOSSIL THALLOPHYTES

Most Thallophytes are soft and fragile, and hence ill-adapted for preservation in the fossil state. Lime-encrusted Siphonales, however, are well represented in Tertiary and Mesozoic strata, and the Silurian and

Devonian *Nematophycus* were large Algæ not unlike some Laminariaceæ. Geologically the Florideæ are the most interesting of Algæ. Two lime-coated genera (*Lithothamnion* and *Lithophyllum*), allied to *Corallina*, at the present day far outnumber the animal corals in many reefs (as in the Mediterranean, the Red Sea, and at Funafuti in the Pacific); and similar "Nullipores" were the builders of limestones as far back as the Ordovician period. As Diatoms are exceptionally well fitted for petrification on account of their resistant siliceous walls, it is rather remarkable that these plants have not been found below the level of the Trias. The beds known as "polishing slates" and "Kieselguhr" consist largely of fossil Diatoms, and similar deposits are now being formed over enormous areas of the ocean bed (diatom ooze), and on a smaller scale in such places as the Yellowstone Park. It has been suggested that the well-known "Oolites" owe their origin to the activity of ancient Cyanophyceæ (*Girvanella*); this theory is borne out by the fact that at the present time small oolitic pebbles are undoubtedly formed by Blue-green Plants in the Great Salt Lake, the Red Sea, and elsewhere; Cyanophyceæ and Bacteria are also concerned in depositing travertine (calcareous stone) and sinter (siliceous deposit) in the Yellowstone Park.

Most of the specimens which have been described as fossil Fungi are very problematic, and the same is true of Bacteria. Negative evidence, however, while it may carry weight in particular cases, does not shake our belief in the great antiquity of most of the group of lower plants; on the other hand, the "record of the rocks" has so far thrown little or no light on the relationships of these groups.

ECONOMIC IMPORTANCE OF THALLOPHYTES

Few of the Algæ are directly useful to man. The importance of Peridineæ and Diatoms for the life of the waters, and the leading part played by Bacteria and Cyanophyceæ in preparing the land for the growth of higher plants, have been explained above. Mention has also been made of the scavenging rôle of the saprophytes among Fungi and Bacteria; the very marked "fermenting" power possessed by many of these is applied in numerous industries (see also CHEMISTRY and AGRICULTURE).

The usefulness of Fungi as fermenting agents (Yeasts, *Mucor Rouxii*) or as destroyers of insect pests (Entomophthorineæ, Cordyceps), and their value as food plants, are more than counterbalanced by the injuries inflicted by parasitic species upon cultivated plants. It is impracticable to mention more than a few of the most destructive fungoid diseases here, since every domesticated plant is liable to be attacked by more than one. The Rusts of cereals (*Puccinia* spp., fig. 209, 11a, b, c) cause almost incredible damage. The loss due to Wheat-rust in Prussia for an "ordinary" year amounts to £1,000,000, but sometimes rises to £20,000,000, while the damage for a bad year in the United States has been estimated at the appalling figure of £62,000,000. The Smuts (species of *Ustilago*, *Tilletia*, and *Urocystis*) are somewhat less destructive than the Rusts, mainly because in their case better means of prevention are available. A

terrible scourge is *Phytophthora infestans*, the best known and most dangerous of the numerous diseases of the potato.

Bracket-fungi (Polyporaceæ) are the chief enemies of timber trees; the Dry-rot (*Merulius lacrymans*), which plays havoc with sawn timber, is allied to these. Other tree destroyers are *Armillaria mellea* ("Hallimasch"), *Dasyscypha* (*Peziza*), *Willkommi* (Larch canker), and several Uredineæ (*Cronartium*, *Gymnosporangium*, Plate, fig. 11, &c.).

The Vine suffers great injuries from the Mildews (*Plasmopara viticola*, False Mildew; *Uncinula necator* [*Oidium Tuckeri*], True Mildew); the fruit-grower is troubled by many special pests (Pocketplums, *Taphrina* spp.; Scabs, *Venturia* spp.; Brown Rot, *Monilia fructigena*; Mildews, spp. of *Sphaerotheca* and other Erysiphaceæ); while the nurseryman and the market gardener have to contend also with omnivorous parasites like *Phytophthora omnivora* or *Botrytis cinerea* (*Sclerotinia* spp.).

CHAPTER VIII

HIGHER PLANTS (ARCHEGONIATES)

LOWER PLANTS AND HIGHER PLANTS.—The phyla which have been dealt with in the two preceding chapters may be collectively termed the LOWER PLANTS in contrast to the remaining groups, namely, the Liverworts and Mosses (Bryophyta), the Ferns and Fern-allies (Pteridophyta), and the Seed-plants (Spermatophyta), which together make up the HIGHER PLANTS. This subdivision of the vegetable kingdom is not only convenient, but also corresponds to a serious gap in the line of descent of the green plants; for the higher tribes are sharply marked off from the Lower Plants in several ways. Thus the plant body in the Higher Plants is, with few exceptions, a LEAFY SHOOT.

ALTERNATION OF GENERATIONS.—Another important feature is the ALTERNATION OF GENERATIONS, which is seen in its most typical form in the Ferns (see fig. 221). The familiar fern plant is the product of a fertilized egg-cell (OOSPORE), but itself produces only asexual germs, the SPORES. A spore on germination gives rise, not to a new fern plant, but to a small body of very simple structure, the PROTHALLUS, which bears sexual germs (antherozoids and egg-cells); an egg-cell, upon fertilization, becomes the starting point of a fresh "plant". It is only among Pteridophytes that this alternation of *independent* sexual (*gametophyte*) and asexual (*sporophyte*) generations occurs. But an essentially similar rhythm in the life-history is found in the rest of the Higher Plants, whereas anything of the kind is not the rule among Algæ and Fungi, where the type of reproduction, as Klebs first proved, often depends upon external conditions (see below, p. 83). How this orderly alternation, characteristic of the Higher Plants, has arisen from the unsettled state which is found in most Lower Plants is quite an open question.

The theory of the "antithetic" origin of alternation is supported by a wide range of facts; it maintains that the algoid or alga-like ancestors of the Higher Plants continued to develop the tendency seen in *Coleochæte* (p. 32), namely, the interposition of vegetative cells and asexual germs between a fertilized egg and a fresh gamete-producing plant.

THE ARCHEGONIUM.—As regards the essentials of the sexual process, the Higher Plants show no advance over the Green Algæ, except in the fact that they are all oogamous. An entirely novel feature, however, is the ARCHEGONIUM, the characteristic flasklike receptacle in which the egg-cell is encased. This structure is best developed in the Bryophytes (fig. 213, 10), but is also found in all the Pteridophytes and in almost all the Gymnosperms. The Angiosperms have a different arrangement, but there is every reason for believing that they are derived from ancestors which had archegonia. The phylogeny of the archegonium is quite obscure; there is nothing like it among Green Algæ, and the oogonium of the Stoneworts throws no light upon its origin.

The principal differences between the Higher and Lower Plants are evidently connected with the contrast in the manner of life of the two divisions. The Thallophytes are typically water plants, whereas the history of the Higher Plants is the record of an invasion of dry land by aquatic beings and of the gradual emancipation of the invaders from a state of dependence upon liquid water. The archegonium serves to protect the egg-cell and to capture the water-borne male gametes; and the regular alternation of generations may perhaps be regarded as a compromise between the better adaptation to land life of the sporophyte on the one hand and the advantages of an occasional act of fertilization on the other.

CYTOLOGY OF THE HIGHER PLANTS.—In several points of minute structure the Higher Plants show greater uniformity than the Thallophytes.

The reduction of chromosomes (see GENERAL BIOLOGY), which in different Lower Plants occurs at very different stages of the life-history, from the Bryophytes upwards always takes place in connection with the formation of the asexual germs. It is indeed a general custom among botanists to define the two generations in the Higher Plants by means of the chromosome number. The latest researches, however, have once more made it doubtful whether the alternation of generations is so strictly dependent on the condition of the nuclei as this custom would imply.

In the Algæ the chromatophores display considerable variety of form and colour; cœnocytic structure is not uncommon, and may even be the rule within a family; the modes in which cells are combined to form a colony or massive thallus are very numerous. In the Higher Plants, the bulky type of plant body in which a relatively small number of cells retain the power of continued growth and division is the rule. The cell typically possesses a single nucleus, although even here cœnocytes occasionally perform important duties. With few exceptions (e.g. *Selaginella*, in which each green cell has only one or two large chromatophores) the assimilating cells contain many small green chromatophores,

devoid of pyrenoids, but nevertheless usually forming starch. A large proportion of the cells of a Higher Plant are colourless, and these vary extraordinarily as regards size and shape, and still more as regards the structure and chemical nature of their walls. It is in these higher tribes that the great possibilities of that characteristic plant-structure, the *cell-wall*, are most fully realized.

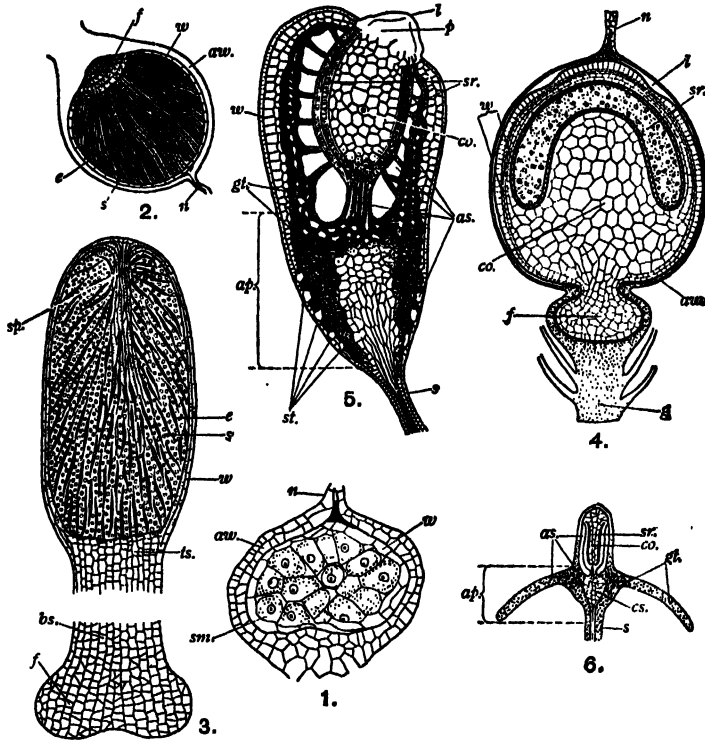


Fig. 211.—Capsules of Liverworts and Mosses. (All in longitudinal section and semi-diagrammatic)

1, *Riccia hirta*. *w*, One-layered wall of capsule; *sm*, spore mother-cells (each will produce 4 spores); *aw*, enlarged wall of archegonium; *n*, remains of neck. 2, *Marchantia polymorpha*. *w*, One-layered wall of capsule; *f*, foot (absorbing organ buried in the gametophyte); *s*, spores; *e*, elaters; *aw*, enlarged wall of archegonium; *n*, remains of neck. 3, *Aneura pinguis*. *w*, Two-layered wall of capsule to top of stalk; *bs*, base of stalk (intermediate portion omitted); *f*, foot; *s*, spores; *e*, elaters; *sp*, central strand from which the elaters radiate. 4, *Sphagnum acutifolium* (half-ripe). *w*, Many-layered wall of capsule; *l*, line along which the lid breaks away; *co*, central sterile mass or columella; at ripeness this breaks away and is replaced by air; *sr*, spore-forming region (here bell-shaped); *f*, foot; *aw*, enlarged wall of archegonium; *n*, remains of neck. The stalk *g* is part of the gametophyte. 5, *Funaria hygrometrica*. *l*, Lid; *p*, peristome; *co*, columella; *sr*, spore-forming region (here barrel-shaped); *ap*, apophysis; *gt*, green (assimilating) tissue (indicated by shading). *as*, air spaces; *st*, air pores (stomata); *s*, top of stalk. 6, *Splachnum luteum*, lettering as in 5.

MOSES AND LIVERWORTS (BRYOPHYTA)

In the Bryophyta the "plant" is the gametophyte; the product of the oospore is always mainly devoted to the nourishment, protection, and spreading abroad of the spores. It is, in fact, essentially a spore case (SPOROΓONIUM or CAPSULE); and although in certain cases this structure may be partly self-supporting, owing to the presence of green cells, an entirely independent sporophyte is never produced (see fig. 211).

The Bryophyta comprise two distinct phyla, the LIVERWORTS (Hepaticæ) and the MOSSES (Musci). We cannot say which of the two groups is the more primitive, especially as no trustworthy Bryophyte fossils have so far been discovered. The Liverworts show the wider range of structure, while the average level of evolution is perhaps rather higher in the Mosses.

LIVERWORTS

In dealing with the Liverworts we may profitably pay attention to the following developments, all of which are concerned with adaptation to life on land:—

1. The evolution of a leafy shoot from a thallus.
 2. A gradual elaboration of internal structure.
 3. An increasing complexity and independence of the sporogonium.
- Each of the three families of Hepatics has made special progress in one of the directions indicated.

GAMETOPHYTE.—In the MARCHANTIALES the plant body is always a thallus; but even in the lowest genus, *Riccia* (fig. 212, 1 and 2), the anatomy is not very simple, while forms like *Marchantia* (fig. 212, 3a-6) are quite complicated. The simplest members of the JUNGERMANNIALES, such as *Aneura* or *Pellia*, also have a thallus; the usual type in this family, however, is a creeping or trailing leafy shoot, with two rows of leaves occupying the flanks of the stem and a third row of smaller leaves or scales on the lower face. Such a form as *Blasia pusilla* (fig. 212, 8) suggests one way in which a thallus may have been changed into a leafy shoot; but there is no doubt that leaves have been evolved independently in different sections of the Jungermanniales, and perhaps in relation to different external influences. Again, in *Hymenophyllum* (fig. 212, 9) there is a distinction between a lower stemlike region and an upper flat surface, a structure which is not a leafy shoot, and yet serves similar ends. *Lembidium dendroideum* (fig. 212, 11) illustrates an advanced type of the Jungermanniales. Besides the assimilating upright branches there are stems penetrating the ground, which are devoid of leaves but covered with absorbing root-hairs (*rhizoids*), and so play the part of roots; here and there the underground branches produce tubers for "hibernation" during drought. Finally, special branches bearing the sexual organs arise from the bases of leafy stems. Many of the special adaptations of Jungermanniales are connected with the storing of water (see *Frullania*, fig. 212, 12, and *Colura*, fig. 212, 13). Very remarkable are the hollow underground reproductive branches of *Calypogeia* (fig. 212, 14), in which the archegonia are sheltered from drought. The anatomy of Jungermanniales is always simple, especially in comparison with the Marchantiales.

SPOROPHYTE.—The CAPSULE of *Riccia* (fig. 211, 1) is the simplest sporophyte known. When ripe it is a small round body consisting of a solid mass of spores which are set free by decay of the single-layered wall—the only "sterile" part of the structure. In almost all Marchantiales and Jungermanniales complications are introduced by the development of

LIVERWORTS

- 1, *Riccia fluitans*; a submerged species; $\frac{1}{2}$ nat. size.
- 2, *Riccia natans*, growing on land; $\frac{1}{2}$ nat. size.
- 3-7, *Marchantia polymorpha*.
- 3*a*, An air-chamber in vertical section; *g*, air-pore; magnified.
- 3*b*, Air-pore seen from above, magnified.
- 4, Gemma, or brood-body; an apical cell lies in each depression (*n*); $\times 30$.
- 5, Portion of thallus with an antheridial branch (*a*), and cups containing gemmæ (*c*); $\frac{1}{2}$ nat. size.
- 6, Head of an archegonial branch seen from below; *sp*., position of a young sporogonium; $\times 1\frac{1}{2}$.
- 7, A burst sporogonium; *e*, mass of spores and elaters; *l*, leafy sheath of the sporogonium; *w*, remains of archegonium-wall; $\times 5$.
- 8, *Blasia pusilla*.
- 9, *Hymenophyllum flabellatum*.
- 10, *Calobryum Blumii*, the leaves are in three rows as in Mosses; $\frac{1}{2}$ nat. size.
- 11, *Lembidium dendroideum*; *t*, tuber; *fb*., fertile branch; $\times 2$.
- 12, *Frullania Tamarisci*, lower face of a branch; *w*, water-sacs; $\times 20$.
- 13, *Colura tortifolia*; *w*, water-sacs; *a*, antheridial branch; $\times 20$.
- 14, *Calypogeia ericetorum*; *l*, leaves; *f*, hollow archegonial branch; *a*, position of the archegonium, and later of the sporogonium; magnified.
- 15, *Anthoceros lævis*; *th*., thallus; *s*, sporogonium; *c*, columella; *w*, wall; $\frac{1}{2}$ nat. size.
- 16, *Anthoceros punctatus*; transverse section through upper part of sporogonium; *c*, columella; *sp*., spores; *e*, feeding cells; *a*, green (assimilating) cells; *i*, air-spaces; magnified.
- rh*., rhizoids; *s*, sporogonium.

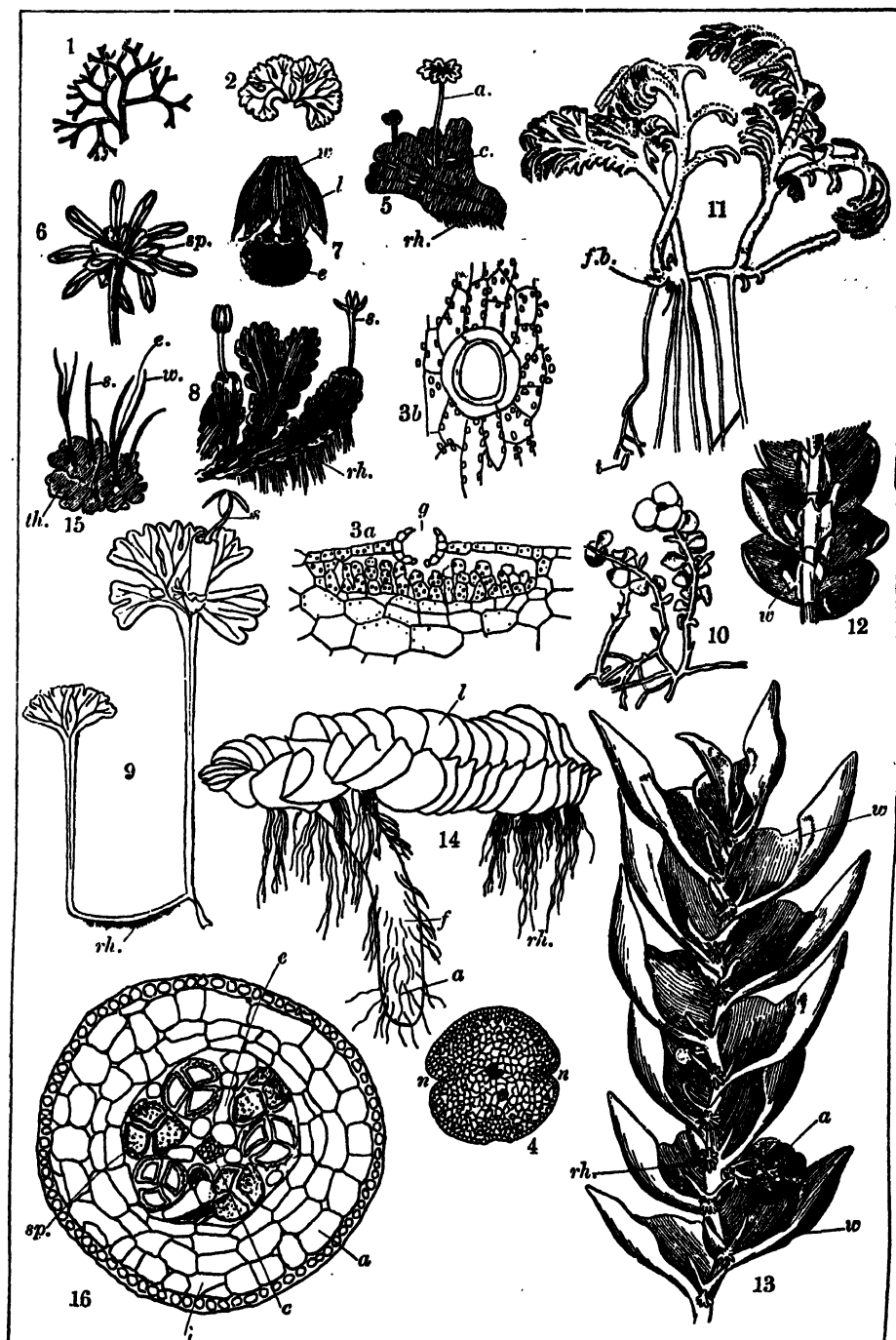


Fig. 212

LIVERWORTS

some of the central cells as "elaters"—hygroscopic threads which assist in dispersing the spores—and by modification of the wall cells so as to enable an active opening of the capsule to take place (fig. 211, 2 and 3; 212, 7-9). It is the small class of ANTHOCEROTALES, however, in which the plant is a simple thallus, that possesses the most advanced type of sporogonium. In the long-lived pod-shaped capsule of *Anthoceros* (fig. 212, 15 and 16) there is a great deal of vegetative tissue comprising an absorbing "foot" which sends forth hairlike outgrowths into the thallus, a central core of conducting cells (columella), and an outer shell of green tissue with air-spaces and air-pores. Just above the foot lies a zone of dividing cells which continually adds to the various tissues of the capsule. If this sporogonium were to come into direct communication with the soil instead of being merely embedded in the thallus, an entirely independent sporophyte would result.

MOSSES OR MUSCI

GAMETOPHYTE.—The erect leafy shoot, which is the obvious plant-body of a Moss, arises as a side-branch from an alga-like system of branching threads, the *protonema*. The latter is the first product of the germinating spore, and persists as an absorbing and fixing portion of the adult. A shortlived protonema is not uncommon among Liverworts, but this soon grows out apically into the permanent plant-body. Both Bryophyte phyla include forms which are filamentous throughout life. Such are the tropical *Protocephalozia ephemeroides* (Jungermanniales); the moss *Ephemeropsis tjibodensis*, which grows upon living leaves in Java; and the saprophytic Buxbaumieæ (Musci). Striking adaptations are perhaps less frequent among Mosses than in the Liverworts; as in that group they are often connected with water-supply. In *Polytrichum* the leaf-margins roll inwards in drying, and shelter the delicate assimilating ridges which cover the upper face of the leaf. The spongy structure of Peat-mosses (*Sphagnum*) and the light-condensing protonema-cells of the Cave-moss have already been mentioned.

SPOROPHYTE.—Many moss-capsules resemble the type of *Funaria* (fig. 211, 5). A large amount of vegetative tissue is developed, especially in the region where the stalk passes into the body of the capsule. In *Splachnum* (fig. 211, 6) this portion is expanded into a disc or hood which has a very leaflike structure. The typical moss-capsule opens by the breaking away of a lid; the pore so produced is fringed by hygroscopic teeth (fig. 213, 8) which ensure that the spores are shed gradually and only in dry weather. Unusual arrangements are found in *Polytrichum* (fig. 213, 4) and *Andreaea* (fig. 213, 13); the sporogonium of *Sphagnum* (fig. 211, 4), which is built upon a special plan, becomes charged with compressed air, and finally bursts explosively.

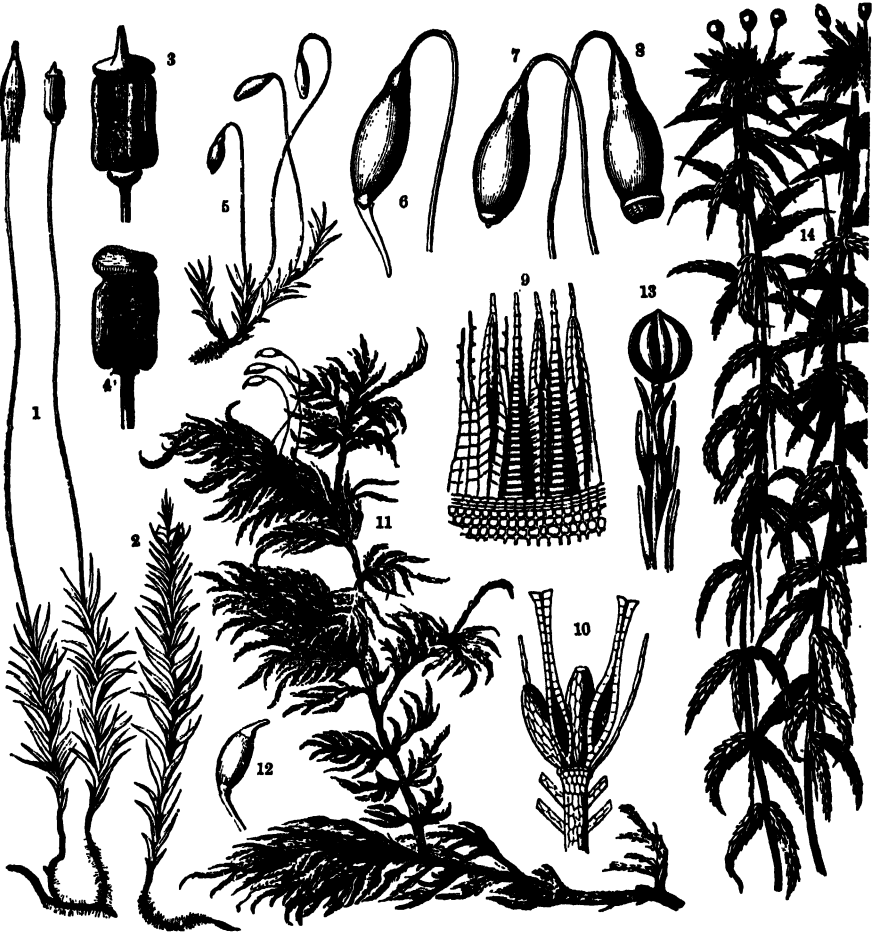


Fig. 213.—Mosses

1, *Polytrichum commune*; the spore-capsule to the left is concealed by the cap (calyptra), that to the right is exposed. 2, The same moss in an earlier stage of development. 3, Spore-capsule of *Polytrichum commune* with its lid. 4, The same after the falling away of the lid. 5, *Bryum caespiticium*. 6, Spore-capsule of same with its calyptra. 7, The same after removal of the calyptra. 8, The same after removal of the lid, showing the teeth (peristome). 9, A portion of the peristome, enlarged. 10, Antheridia, archegonia, and paraphyses of *Bryum caespiticium*. 11, *Hylacomium splendens*. 12, Spore-capsule of same. 13, *Andreea rupestris* with burst spore-capsule. 14, *Sphagnum cymbifolium*; the spore-capsules are still intact in the left-hand specimen. 1, 2, 5, 11, 14, natural size; 3, 4, 6, 7, 8, 9, 10, 12, 13, $\times 150$.

PTERIDOPHYTA OR VASCULAR CRYPTOGRAMS

In all VASCULAR CRYPTOGRAMS the asexual generation is an independent leafy plant, and is more highly developed than the gametophyte. This prominence of the sporophyte is no doubt in part connected with the fact that here for the first time we meet with true ROOTS (fig. 214), which differ from the absorbing and fixing structures of lower groups not only in their greater size, but also in the presence of special conducting cells. Such VASCULAR TISSUE, comprising at the least *wood* for water-conduction, and *bast* for the transference of "manufactured"

materials, plays an important part also in the stem, and often in the leaf as well. In other respects the various groups of Pteridophytes differ considerably among themselves. They must have separated from one another in early Palæozoic times, and it is improbable that there will ever be certainty as to their true relations to one another; still less can we hope for a fossil record of the origin of the independent sporophyte.

If we accept the "antithetic" theory of alternating generations (see above, p. 48), the following general statements are supported by the comparative study of both adult plant and embryo in the various Pteridophyte families. The "sterilizing" process already seen in the spore-cases of Bryophytes (fig. 211), whereby an increasing number of cells, originally

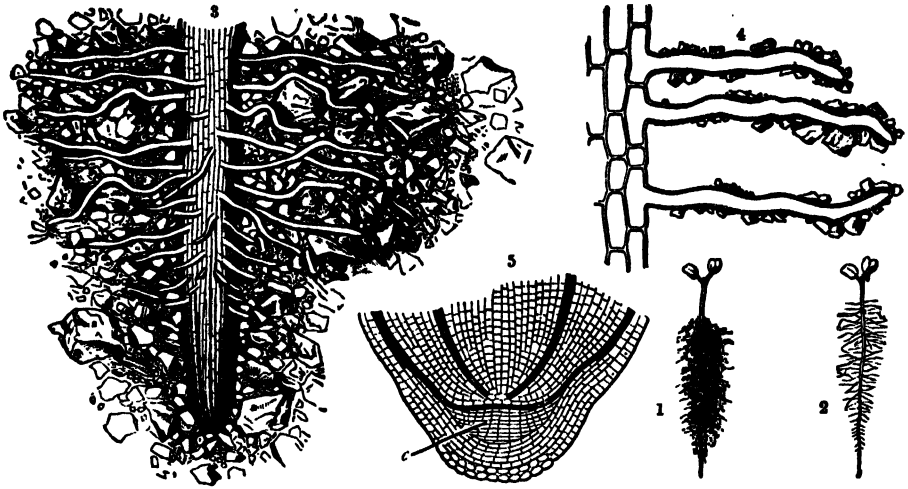


Fig. 214.—Root of a Vascular Plant (*Pentstemon*)

1, Seedling with the long absorptive cells of its root ("root-hairs") with sand attached. 2, The same seedling; the sand removed by washing. 3, Root-tip with absorptive cells; $\times 10$. 4, Absorptive cells with adherent particles of earth. 5, Section through the root-tip; $\times 60$. 6, root-cap.

spore-producing, are devoted to vegetative work (storage, conduction, or assimilation), is here carried much further, so that the region in which spores are produced is no longer compact, but is broken up into several tracts (SPORANGIA) separated by sterile tissue. The STEM of the Pteridophyte plant has been directly derived by this sterilization from a sporogonium-like structure, and is thus historically the oldest part of the sporophyte. The assimilating LEAVES, the BRACTS or protective leaves which often accompany the actual spore-bearing organs, and the ROOT which completes the independence of the sporophyte, are all outgrowths of later origin.

The plant-body is often more or less sharply divided into a vegetative portion and a spore-producing region, the STROBILUS or cone. By branching and long-continued growth both the feeding capacity and the output and chance of survival of spores is increased. Other views as to the origin of "alternation" lead to interpretations which are totally different from those just put forward. Indeed the evidence from all

sources does not at present admit of a decision between a number of possible theories of the mode of origin of vascular plants.

CLUB-MOSSES OR LYCOPODIALES

VEGETATIVE ORGANS.—The typical living LYCOPODIALES are the Club-mosses proper, belonging to the genus *Lycopodium*. They are small evergreen herbs, with a more or less branched stem bearing very numerous small leaves, and below producing forked roots. The sporangia are attached singly to leaf-like bracts, which are usually collected into cones. An even simpler arrangement prevails in *Lycopodium Selago* and allied species, in which the shoot shows a succession of fertile and sterile zones, and the sporangium-bearing and the barren leaves are alike in shape and size. The curious little *Phylloglossum* agrees in all essentials with *Lycopodium*.

The other type of Club-moss is distinguished by the possession of the *ligule*, a small appendage attached to the upper side of the leaf near its base. The living genera (*Selaginella*, *Isoetes*) are small herbs, but in Carboniferous rocks Lycopods of this type are abundantly represented, mainly by large trees like *Lepidodendron* (fig. 215) and *Sigillaria*, although recently a few herbaceous forms (*Adiantum*, *Selaginella*) have been discovered in the same strata.

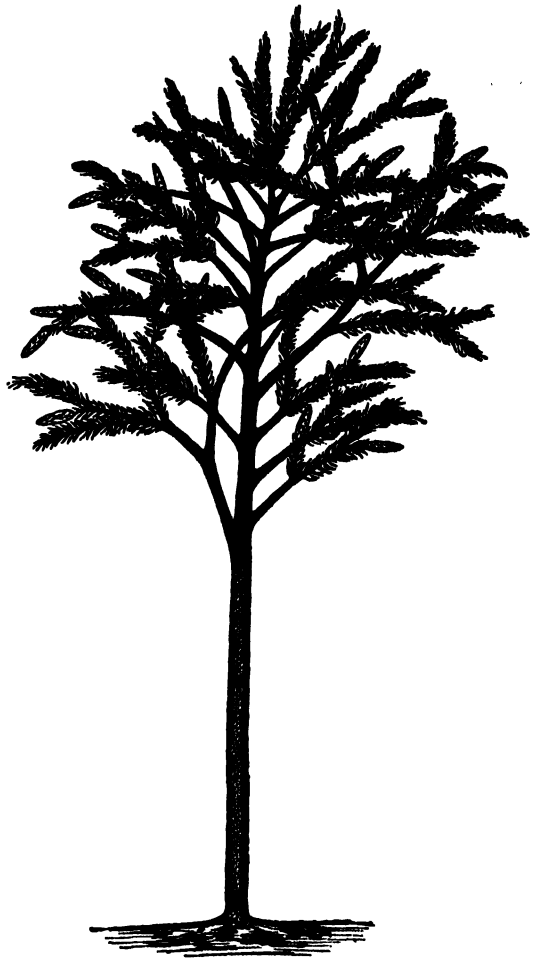


Fig. 215.—Restoration of a *Lepidodendron*, one of the giant Club-Mosses of the Coal-period

SPORES AND GAMETOPHYTES.—The spores of *Lycopodium* and *Phylloglossum* grow out into prothalli which are the bulkiest and most elaborate gametophytes known among Vascular Plants. In *Selaginella*, on the other hand, there is a very far-reaching reduction of the sexual generation. This genus is the classic example of HETEROSPORY, that is to say, the formation in separate sporangia of distinct small and large

spores (*microspores* and *megaspores*) giving rise respectively to male and female gametophytes (figs. 216, 217).

The origin of heterospory, which has appeared independently in several groups of Vascular Plants, is possibly to be sought in differences of nourishment in different parts of the fertile shoots. In itself it has perhaps not caused serious modification of structure; but it is of the

greatest importance as a first step towards the evolution of the structure that we call the SEED. The general meaning of the reproductive arrangements of *Selaginella* is fairly clear, although the actual stages in its evolution are not known. The ripening of only a small number of spores in the large sporangium (in some species as many as sixteen, in others as few as one) is still actually the result of a struggle for food among a great many potential spore-producing cells (fig. 216, 3). By a delay in the separation of the megaspores from the parent plant until after germination, the female prothallus is enabled to feed parasitically on the sporophyte; on this account, and also, no doubt, through lack of room, the prothallus

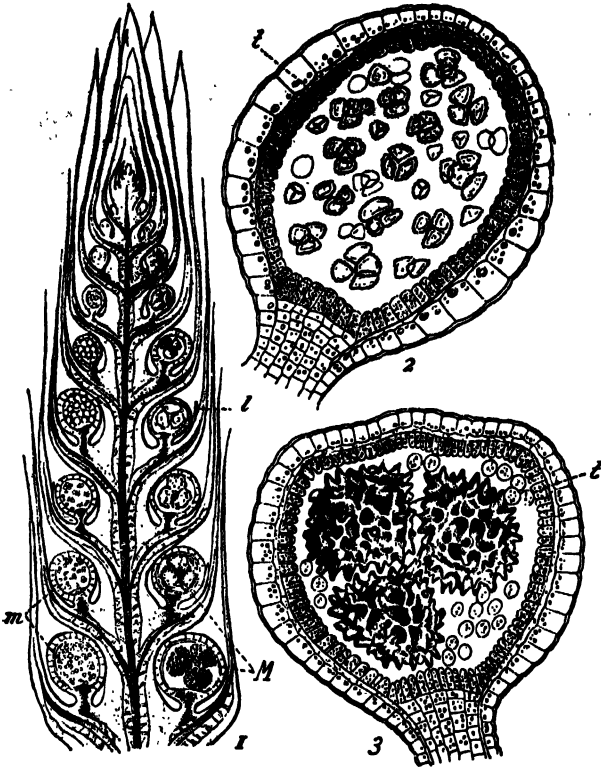


Fig. 216.—*Selaginella*

1, Vertical section of a cone (somewhat diagrammatic). *l*, Ligule of the bract; *m*, microsporangium; *M*, Megasporangium. 2, Vertical section of a Microsporangium. *l*, The nursing-layer (tapetum) of the wall. 3, Vertical section of a megasporangium. A single spore mother-cell has ripened and produced four megaspores (three only are figured). Other spore mother-cells are seen in process of degeneration.

gives up vegetative work and becomes practically a "base" for the archegonia and a storehouse of food for the immediate use of the embryo.

Only one species of *Selaginella* (*S. rupestris*) actually retains the megaspores upon the parent sporophyte until the embryo is ready to shift for itself, and the *Selaginellas* in any case are not to be regarded as the ancestors of any of the seed-plants; but the explanation suggested in the case of this Lycopod genus probably applies in the main to the evolution of all seeds. The male prothallus is more simplified even than the female in *Selaginella* (and in other heterosporous plants). The origin of the reduction is less obvious here; but it is certainly connected with

the fact that the small spores in such plants are carried bodily to the neighbourhood of the large spores, an arrangement whereby the path which has to be traversed by the antherozoid is greatly shortened. In

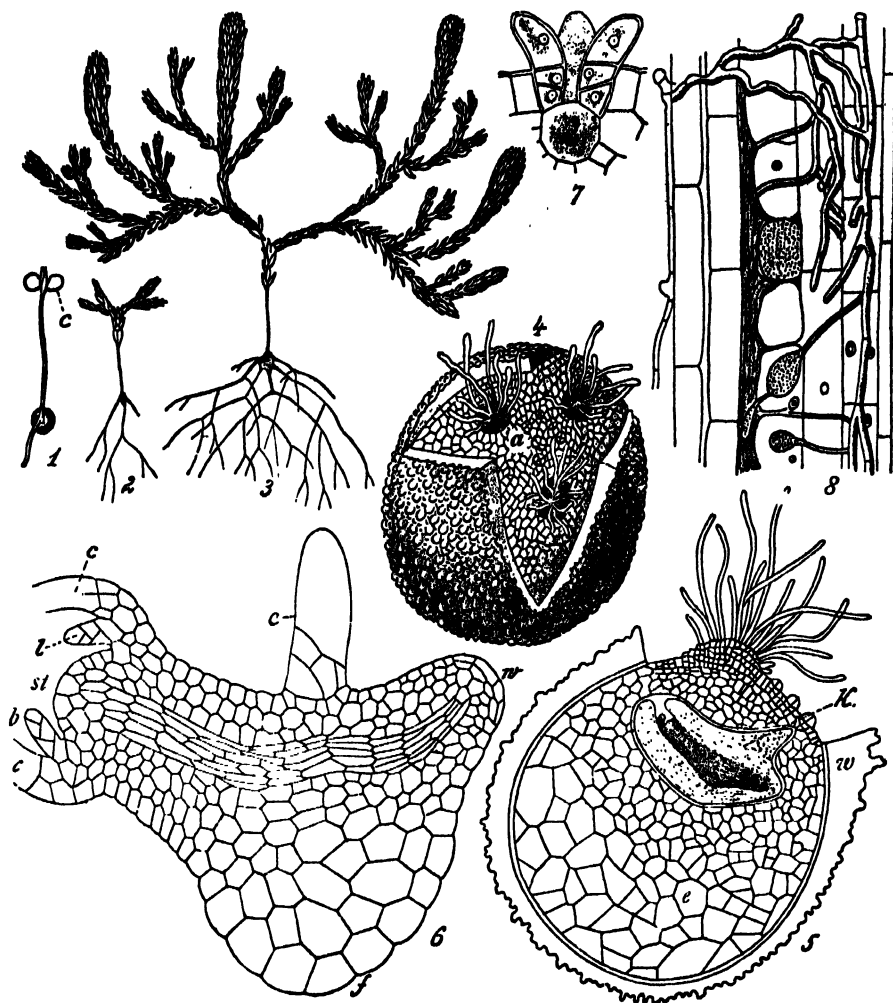


Fig. 217.—*Selaginella*

1, 2, 3, Three stages in the development of the sporophyte. 4, Germinating megaspore. The spore wall is ruptured, and the upper part of the female prothallus exposed. 5, Young archegonium. 6, Embryo in detail. *w*, Young root; *f*, foot; *st*, young stem; *l, l'*, first pair of leaves with their ligules; *s*, suspensor, which by its elongation pushes the embryo down into the nutritive part of the prothallus (*s* in fig. 5). 7, Ripe archegonium. 8, Vertical section of an egg-cell has been fertilized, and has produced an embryo. *K, w*, Spore wall.

the Lycopod phylum heterospory appears again in the curious Quillworts (*Isoetes*), in *Selaginellites*, in *Lepidodendron*, and in *Miadesmia*; in the last genus, and in certain species of *Lepidodendron*, seed-like structures with arrangements for trapping the microspores are found.

HORSETAILS OR EQUISETALES

In the HORSETAILS (EQUISETALES) the leaves are poorly developed in comparison with the stem, just as in the Club-mosses. In the living forms indeed, comprised in the single genus *Equisetum* (fig. 218), the

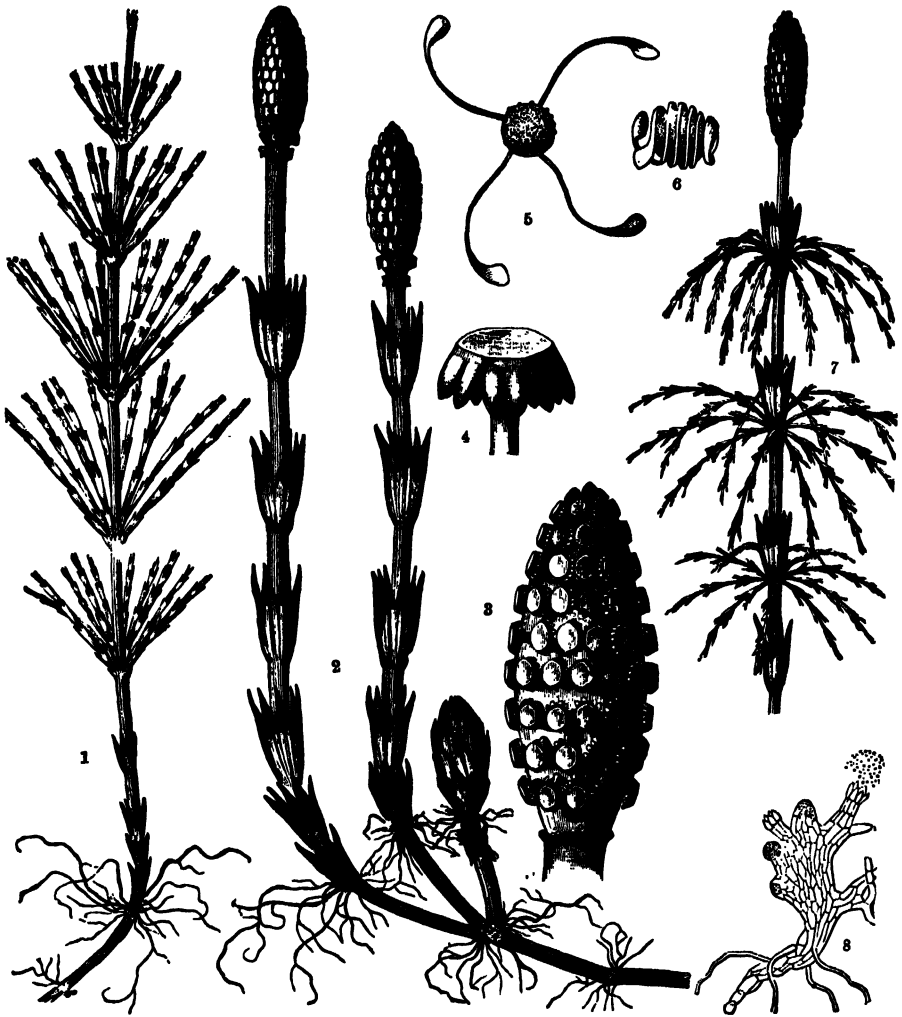


Fig. 218.—Horsetails

1, Summer shoot of *Equisetum arvense*. 2, Vernal fertile Shoot of *Equisetum arvense*. 3, Spike of whorled sporangiophores from the same *Equisetum*. 4, A single sporangiophore. 5, 6, Spores. 7, *Equisetum sylvaticum*. 8, Male prothallium of a Horsetail. 1, 2, 7, natural size; 3, $\times 3$; 4, $\times 6$; 5, 6, $\times 25$; 8, $\times 30$.

leaves are mere scales, and leaf-work is performed by the stem; bracts are also absent from the cones. This group, however, is at the present day only a remnant of its former self. In the Carboniferous swamps there flourished giant Horsetails, the CALAMITES (*Calamariææ*), with thick, woody trunks, often nearly 100 ft. in height; their leaves, though not

large, were much better developed than those of the living *Equiseta*, and in their cones (fig. 219) bracts were usually associated with the spore-bearing structures. Some of the Calamites were heterosporous. The present-day Horsetails have spores which appear to be all of one kind;

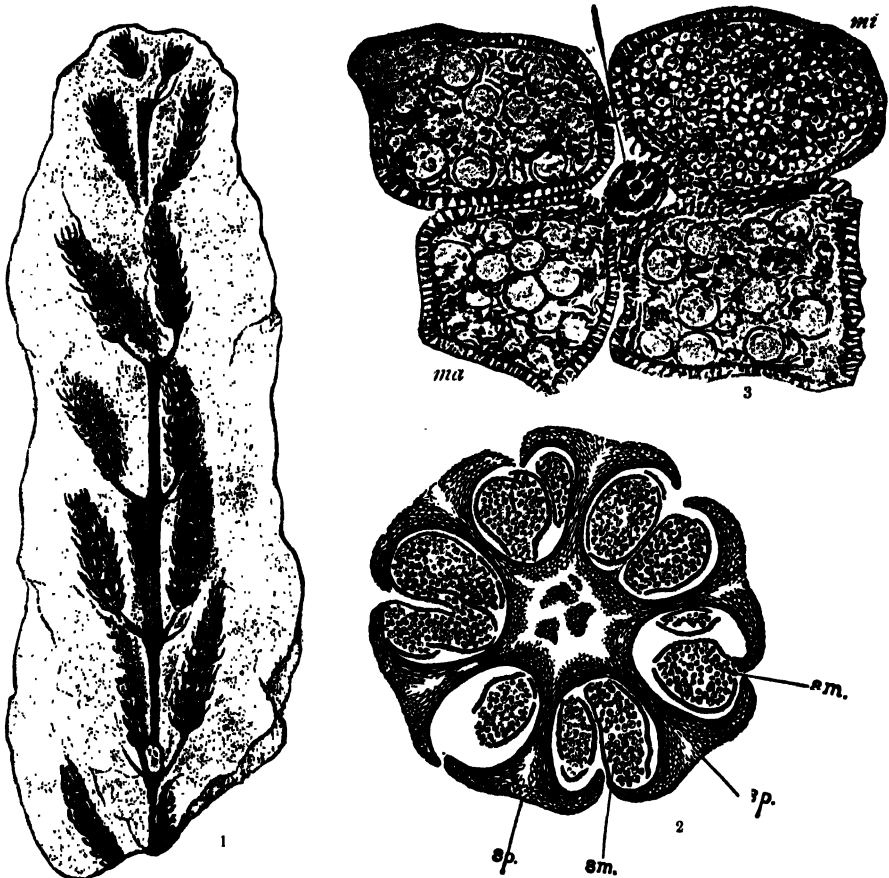


Fig. 219.—Sporangia of Calamites

1, Fertile branch of a Calamite (*Paleostachya*), having numerous cones with conspicuous bracts. 2, Section across the cone of a homosporous Calamite. *sm*, Sporangium; *sp*, sporangium-bearing organ (sporangiophore). 3, Section showing a group of four sporangia of a heterosporous Calamite; *mi*, microsporangium; *ma*, megasporangium.

on germination, however, they give rise to separate male and female prothalli, differing in form as well as in sex. The strap-shaped lobes into which the outer layer of the spore wall splits (fig. 218, 5 and 6) serve to chain together a number of spores, and so to ensure that antherozoids and egg-cells are produced within reasonable distance of one another.

WEDGE-LEAVED PLANTS OR SPHENOPHYLLALES

The phylum of SPHENOPHYLLALES or WEDGE-LEAVED PLANTS consists entirely of Palæozoic species belonging mostly to the genus *Spheno-*

phyllum. They had slender ribbed stems and whorls of leaves, which in some species were wedge-shaped (hence the name *Sphenophyllum*). Outwardly they were not unlike the *Calamites*, but their anatomy was very different, and probably more primitive. Some, though not all, of the cones belonging to this group are very complicated, notably the remarkable *Cheirostrobus pettycurensis*, which, although it occurs at the base of the Carboniferous formation, is, according to Dr. Scott, the most complex Pteridophyte fructification at present known.

BARE-STEMMED PLANTS OR PSILOTALES

The two small tropical and subtropical genera *Psilotum* and *Tmesipteris* comprise the only living plants which are at all like the extinct

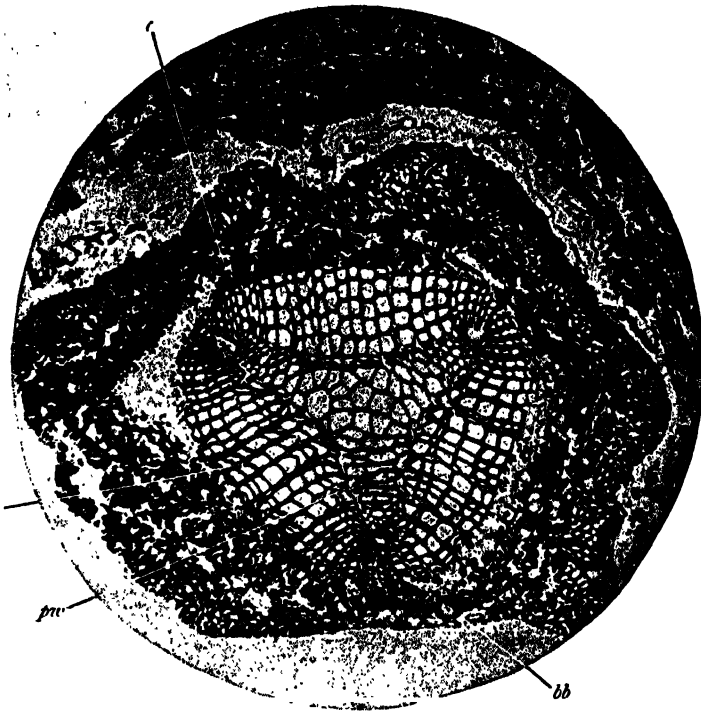


Fig. 220.—Part of a Transverse Section of a *Sphenophyllum* Stem (microphotograph)

pw, Primary wood; *sw*, secondary wood; *c*, position of cambium; *bb*, bast and bark.

Sphenophyllales. They are rootless and half saprophytic, and have small (*Tmesipteris*) or almost abortive (*Psilotum*) scattered leaves. The stem structure resembles that of *Sphenophyllum*, and the arrangement of the sporangia, which are not collected into cones although they occupy fairly definite fertile regions on the shoots, recalls one of the simpler *Sphenophyllum* fructifications (*S. majus*).

FERNS OR FILICALES, AND ADDERSTONGUES OR
OPHIOGLOSSALES

The various families which are usually classed as FERNS have one feature common to all and distinguishing them from the other tribes of

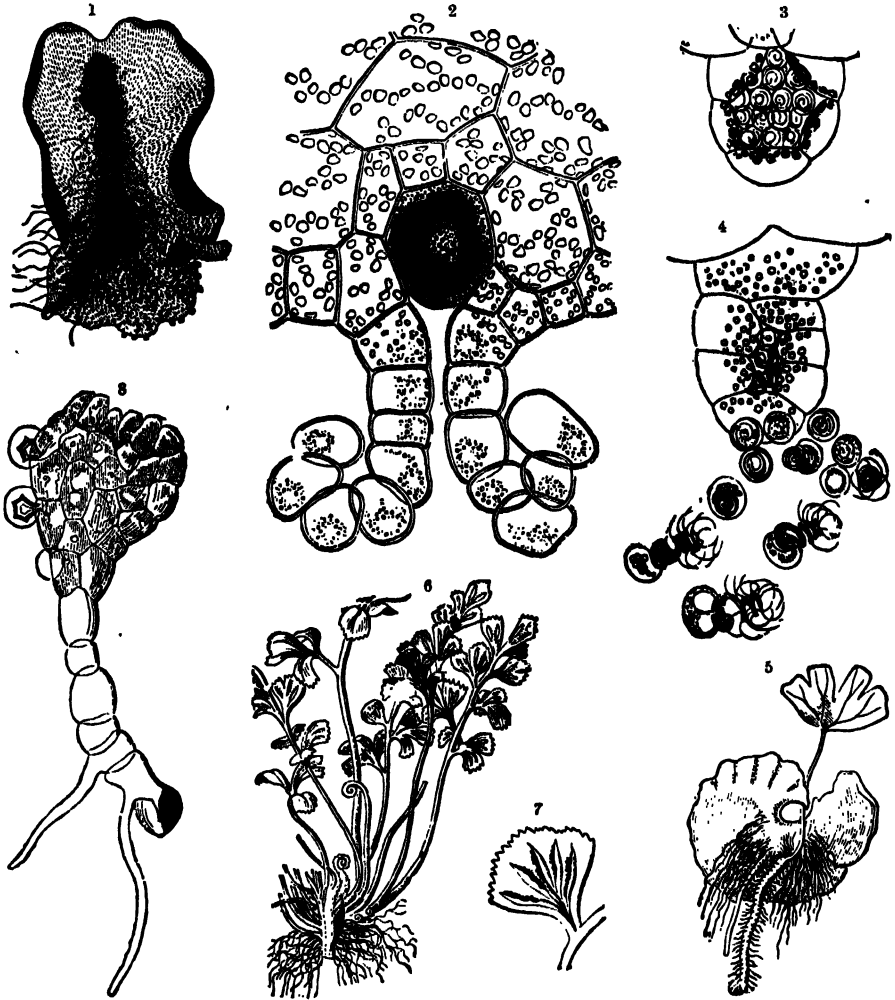


Fig. 221.—Life-history of a Fern

- 1, A Fern-prothallus seen from the under side. 2, An archegonium in longitudinal section. 3, An antheridium. 4, Escape of antherozoids from antheridium. 5, Young sporophyte with first leaf arising from the prothallus. 6, Complete sporophyte of *Asplenium Ruta-muraria*. 7, Under surface of pinnule of same, showing linear sori. 8, A young prothallus arising from a spore; the spore is below. 6, natural size; 1, $\times 8$; 2, 3, 4, $\times 350$; 5, $\times 6$; 7, $\times 3$; 8, $\times 240$.

Vascular Cryptogams. The leaves are always large in comparison with the stem, and the sporangia are usually scattered in small groups (*sori*) over the ordinary leaves or over slightly modified fertile leaves. It has long been the custom to separate two families (Marattiaceæ and Ophio-

glossaceæ), which have bulky sporangia like the majority of Pteridophytes, as *Eusporangiate* Ferns, from the *Leptosporangiate* section, comprising the great mass of Ferns, and distinguished by the delicate superficial sporangia. Now the Adderstongues probably form a separate phylum (OPHIOGLOSSALES) not immediately related to the true Ferns; and the different families of Ferns show a perfect gradation in the bulk of the sporangium. It seems better to lay stress, as Professor Bower has done, upon differences in the order of development of the sporangia in a sorus. In certain families (*e.g.* Botryopterideæ, Marattiaceæ, Osmundaceæ, Matonineæ) all the sporangia of a sorus ripen at the same time (*Simplices*); in another set (*e.g.* Hymenophyllaceæ and Cyatheaceæ) there is a regular succession in space and time, the sporangia succeeding one another on a somewhat raised "receptacle", with the youngest next the base (*Gradatæ*); in a third class (*Mixtæ*), which includes the great majority of modern Ferns (especially Polypodiaceæ) the sorus is flat and wide, and sporangia of various ages are mingled without regard to any obvious plan. If we regard the "simple" arrangement as the most primitive, the "mixed" as the most advanced, and the "graded" as intermediate, we arrive at a classification of Ferns which is not only supported by a comparative study of the plant-body and of the prothallus, but which also agrees very well with the geological facts. For the Palæozoic Ferns were mostly *Simplices*, belonging either to Marattiaceæ (such as the Tree-fern-like *Psaronius*), or to the Botryopterideæ, an extinct family which had features in common with several more recent groups of Ferns. In the Mesozoic period *Gradatæ*, rare in older rocks, become frequent, especially the Cyatheaceæ, to which the existing Tree-ferns belong. The most important *Simplices* of that period were the Matonineæ, now represented only by two species of *Matonia*, which are confined to a small area in Malaya. The "mixed" type is essentially modern, and as already stated is in the ascendant at the present time.

The most important general tendency of the Ferns is towards reduction in size of each sporangium, production of more numerous sporangia, and arrangement of the sorus so as to ensure at once proper nourishment of each sporangium, and room for the carrying out of slinging movements, whereby the spores are thrown to a distance.

INTERNAL STRUCTURE OF PTERIDOPHYTA.—The plant body of the Vascular Cryptogams is built up of a considerable variety of tissues, though these families are in that respect less complicated than the Seed-plants (*q.v.*). Great importance is usually attached in the study of descent to the vascular tissues, partly because they are believed to be less liable than other structures to change under the influence of the environment. This idea is plausible but requires confirmation, especially by experiment. Sphenophyllales and Psilotales have the simplest vascular arrangement, a central strand of wood surrounded by a sheath of bast; *Lycopodium* is not very different. This centralized type recalls the conducting core found in the *Anthoceros* capsule, in a Moss capsule and its stalk, or even in the stem of many a Moss plant (gametophyte). In the rest of Pteridophyta

there are complications; usually the vascular mass becomes broken up in various ways, apparently in order to meet the demands of large leaves (Filicales) or of abundant branches (Selaginella).

ECOLOGY OF PTERIDOPHYTA.—The many special adaptations of the Pteridophyta need not be discussed in detail. Fig. 222 shows the extraordinary reproductive arrangements of *Azolla*, a member of the Salviniaceæ, one of the two known families of heterosporous Ferns. *Azolla filiculoides* is a small floating plant of American origin, but now common in the tropics and in hothouses. The microspores are cemented together into packets (massulæ), which have outgrowths resembling miniature grapnels and serving to anchor the massulæ to the warty cover of the floating megaspores. This is one of the most remarkable arrangements that exists for overcoming the obstacle put in the way of fertilization by heterospory (cp. Selaginella, p. 56).

SEED-PLANTS OR SPERMATOPHYTES

The formation of a true seed is universal in the two plant alliances which are in other respects the most advanced, namely, the GYMNOSPERMS and the ANGIOSPERMS. In these SEED-PLANTS the megasporangium, usually known as the *nucellus*, becomes overgrown by one or two coats, the *integuments*, which do not, however, completely cover its apex, but leave open a cleft or channel, the *micropyle*. The whole structure is called an *ovule*.

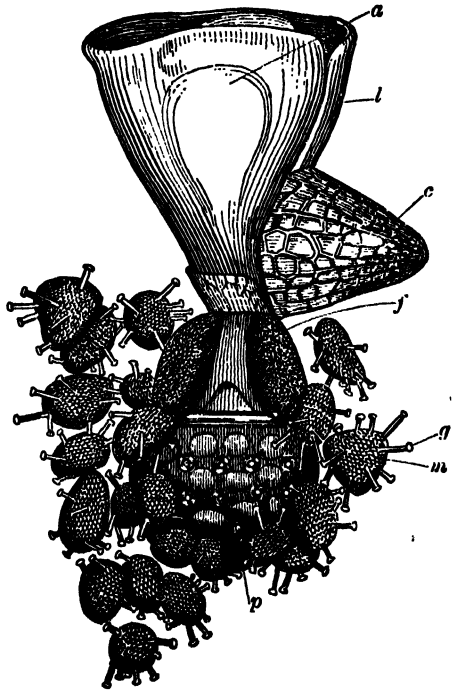


Fig. 222.—*Azolla filiculoides* (magnified)

A megaspore has germinated and given rise to a small prothallus, which, in its turn, has produced an embryo. *b*, Peg-like protuberances of the megaspore wall; *f*, floats of the megaspore; *c*, cap-shaped upper part of megasporangium wall, pushed to one side by the embryo; *a*, bud of embryo seen through the funnel-shaped first leaf (*d*); *m*, packets of microspores; *g*, their hooked processes.

GYMNOSPERMS

As regards the megaspore and the female prothallus, most GYMNOSPERMS have not advanced very far beyond the condition of Selaginella. But in the manner of fertilization, and in other ways, there are important new departures.

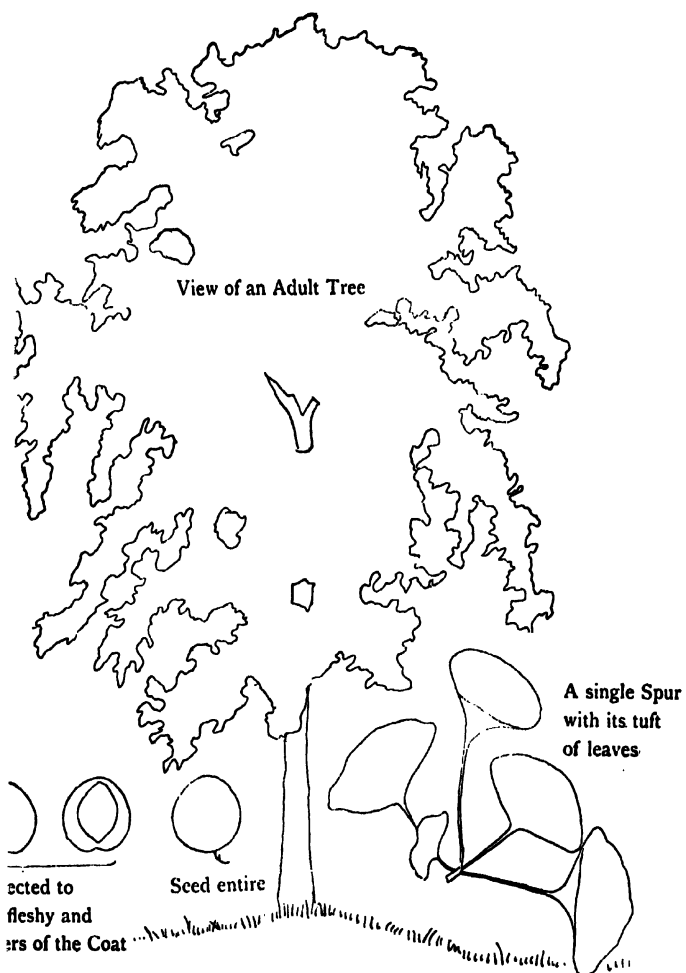
CONIFERALES.—It is convenient to begin with the CONIFERS, although they are by no means the most primitive Gymnosperms. All Conifers are woody plants, and most of them are tall trees after the

pattern of the familiar Pines (*Pinus sylvestris*, &c.), Firs (*Abies* spp.), and Spruces (*Picea* spp.), with very well-marked trunks and regularly arranged branches bearing narrow leathery evergreen leaves (needles). In this type of Conifer the ovules are attached, often in pairs, to special scales crowded together in cones; the microsporangia or *pollen-sacs* are frequently arranged in a similar way. In the nucellus a single megaspore ripens and germinates to form a large mass of cells, the female prothallus or *endosperm*, which nearly fills out the nucellus; in this mass, at the end nearer the micropyle, reduced but still easily recognizable archegonia develop. The young pollen-grain or microspore contains a single nucleus. During ripening two small "vegetative" cells are cut off, which soon disorganize; these may be regarded as the vegetative part, now quite useless and degenerate, of the male prothallus, while the remaining large cell is comparable to a single antheridium. The ripe pollen-grain contains two nuclei, a large "tube-nucleus", and a smaller "generative nucleus". Thanks to the two bladder-like expansions of the wall, it can be carried a long way by the wind. Further development takes place when the grain has lodged in the micropyle of an ovule; a POLLEN-TUBE is put forth, which bores into the nucellus like a fungus hypha, and slowly but surely makes its way towards an archegonium. While the tube-cell controls the growth of the pollen-tube, the generative cell divides, and one of the resulting cells in its turn gives rise to two male gametes. The end of the tube now bursts, the contents are injected into the egg-cell, and the latter is fertilized by one of the male gametes. There is here a very important advance upon Selaginella, in the fact that the pollen-tube has made fertilization independent of the presence of water or other liquid in contact with the archegonium.

The ripe seed comprises (*a*) the embryo, consisting of the rudiments of stem and root, together with two or more seed-leaves (cotyledons); (*b*) the endosperm (female prothallus), filled with food-materials, surrounding the embryo; and (*c*) the woody, leathery, or fleshy seed-coat derived from the integument. This "telescoping" of three generations is characteristic of true seeds. The fertilization by means of a pollen-tube separates the Conifers sharply from any Vascular Cryptogams, and there are also considerable differences in vegetative structure; but the large-leaved CYCADALES and CORDAITALES stand much nearer to the Pteridophyta in both respects, while the GINKGOALES have points in common on the one hand with Cycads, and on the other with Conifers.

GINKGOALES, CYCADALES, AND CORDAITALES.—The GINKGOALES were at one time abundant and widespread; their remains are plentiful, for example, in the Jurassic rocks of the Yorkshire coast. Only a single species has survived to the present day, namely, the Maidenhair Tree (*Ginkgo biloba*), cultivated from time immemorial in Chinese and Japanese temple-gardens, but unknown in the wild state. This plant is not unlike a Conifer in general appearance, but the leaves at once recall certain ferns. The CYCADS (fig. 223) are quite fernlike in appearance, and there are strong resemblances to Filicales in the anatomy, especially in that of the leaves.

Ginkgo, and those Cycads of which the reproduction has been studied



THE MAIDENHAIR TREE



THE MAIDENHAIR TREE

AFTER A CHINESE WATER-COLOUR DRAWING

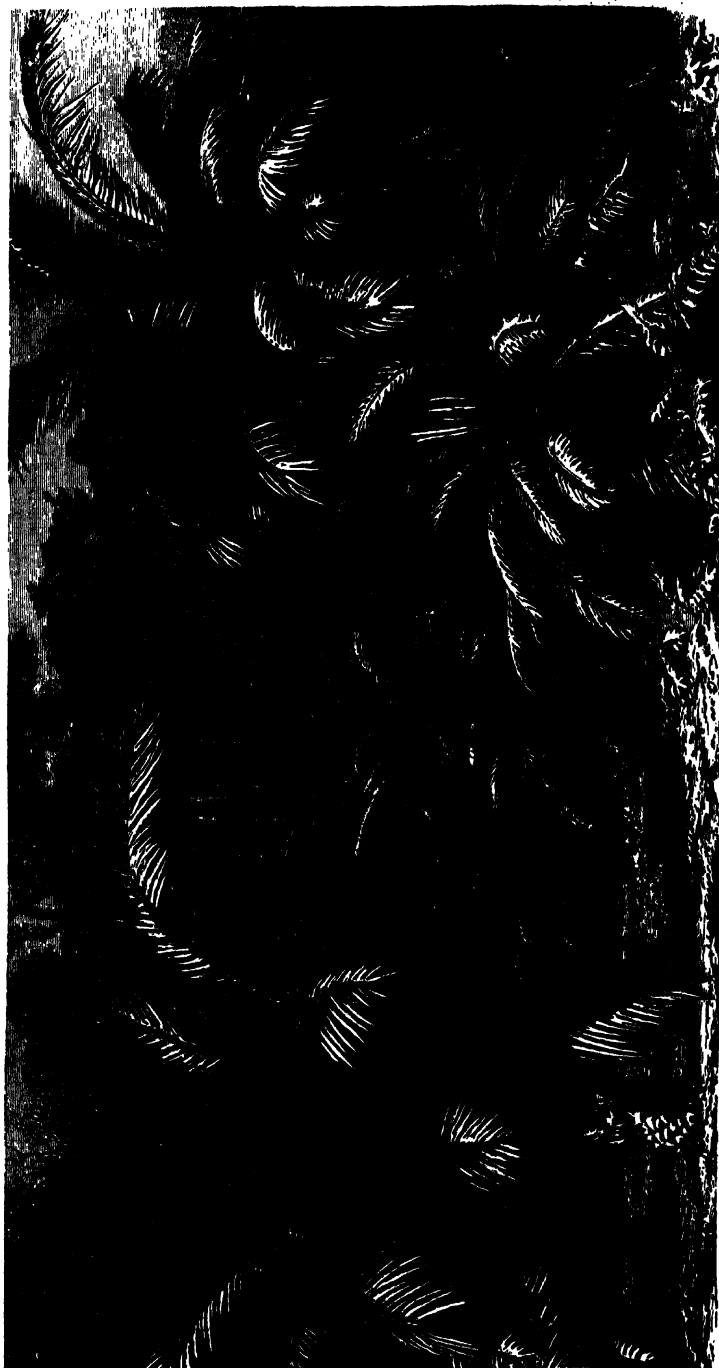


Fig. 223.—A group of *Cycas revoluta*. (From a photograph.)

in detail, form pollen-tubes. The two large male gametes, however, which are formed in the pollen-grain, have each a band of motile protoplasmic threads (flagella). They do not enter the pollen-tube, but drop into a trough in the nucellus; the archegonia open on to the floor of this trough, and when they are ripe, it is filled with a liquid through which the male gametes swim to the egg-cells. Here the pollen-tube takes no immediate part in fertilization, but serves mainly to fix the pollen-grains, and to feed them at the expense of the nucellus. The transformation of a rhizoid of the male prothallus into a gamete-carrier is a very remarkable example of the way in which an important special organ may be evolved from a structure which itself serves a totally different purpose.

The CORDAITALES were the principal Gymnosperms of the Coal Age, but they existed even in Silurian times. They were tall, slender trees, with long narrow leaves resembling single leaflets of a Cycad-leaf (*Cordaites*), or in some cases like gigantic grass-blades (*Poacordaites*). While the ovules were like those of Cycads or of Ginkgo, the pollen-grains on germination produced quite a large mass of cells. Possibly a large number of male gametes were formed. Although a single pair is the rule among living seed-plants, two interesting exceptions have recently been described. The Cycad *Microcycas* forms sixteen antherozoids from each pollen-grain, and from twenty to forty-four nuclei occur in the pollen-tube of *Araucaria*, the type of a group of Conifers (*Araucariæ*) which there is good reason to regard as relatively ancient.

GNETALES.—The affinities of the GNETALES are quite obscure. They seem to approach the Angiosperms in certain features; but it is doubtful whether the resemblance is more than accidental, and this peculiar group is mentioned here chiefly because it includes *Welwitschia mirabilis*, of which some account was given above (p. 6) in connection with the ecology of desert-plants.

SEED-BEARING FERNS OR PTERIDOSPERMEÆ

Fern-like plant remains are exceedingly common in the Palæozoic rocks, and until quite recently Ferns were naturally regarded as the dominant plants of that period. About the end of the last century it was found necessary to set up a new class of CYCADOPILICES, to include plants like the species of *Lyginodendron* (Coal-measures) and *Heterangium* (Carboniferous and Permian), which stand anatomically midway between Ferns and Cycads. But no one was prepared for the revolution of ideas which began in 1903 when Professor Oliver proved that the complicated seed known as *Lagenostoma Lomaxi* belonged to *Lyginodendron Oldhamium* (see plate). These seeds were borne on special fertile fronds, and each was enclosed, like a hazelnut, in a husk or cupule. Two years later Mr. Kidston discovered that the microsporangia of this species were attached in groups to leaves which also produce ordinary leaflets, just like the sporangia of most Ferns; they had, in fact, previously been ascribed to the Marattiaceæ under the name of *Crossotheca*. *Lyginodendron Oldhamium* thus shows a most unex-



Adventitious Roots

•
LYGINODENDRON OLDHAMII (Restoration)

A FERN-LIKE SEED-PLANT FROM THE COAL-MEASURES

pected combination of Gymnosperm and Fern characters. We now also know seeds belonging to the Treefern-like MEDULLOSEÆ (Neuropteridæ) of the Coal-measures, plants with a very peculiar internal structure, but probably related to the Lyginodendreæ, and others borne upon less-known fernlike leaves (*Aneimites*, *Pecopteris*, &c.); in fact, except for the Botryopteridæ (p. 62) and some Marattiaceæ, few of these ancient "Ferns" at present escape the suspicion of being seed-plants in disguise.

The recognition of these Pteridospermeæ (Seed-bearing Ferns), as the Cycadofilices with seeds are now suitably called, strikingly confirms the great antiquity of seed-plants, a fact already established by the early occurrence of Cordaitales. Carboniferous plants are known which perhaps connect Cordaitales with Lyginodendreæ, and others which perhaps link up Lyginodendreæ with true Ferns. But there is little doubt that several great groups of seed-plants were in existence long before the Carboniferous Age.

In the face of this conclusion we can hardly dare to hope that the palæontologist will ever unearth the origins of the more ancient phyla of Vascular Plants, however greatly he may continue to perfect our knowledge of each tribe, and to add to the wonderful variety of fresh types which he has already discovered.

CHAPTER IX

ANGIOSPERMS

The chief differences between the ANGIOSPERMS and the Gymnosperms are connected with the reproductive structures.

MEGASPORANGIUM AND MEGASPORE

The ovules are here enclosed in a closed chamber, the OVARY; its wall is composed of one or more CARPELS, structures which often, but not always, themselves bear the ovules. The pollen cannot come into direct contact with the ovules, but is received upon a special outgrowth of the ovary, the STIGMA. In the nucellus a single megaspore ripens in the typical case, as in *Pinus*; its behaviour on germination, however, is markedly different from that of any Gymnosperm megaspore. The structure of an adult embryosac—as the product of the megaspore is called—in one of the Lilies may be seen in fig. 224, 1. Three naked energids, the egg-cell (oosphere) and the two "helping cells" (synergidæ), make up the EGG APPARATUS at the end next the micropyle; at the opposite end are the three ANTIPODAL CELLS; while two POLAR NUCLEI lie together in the middle of the sac. Clearly a coherent female prothallus is wanting, and archegonia are not developed.

MICROSPORANGIUM, MICROSPORE, AND MALE PROTHALLUS

The pollen sacs do not differ greatly from those of Gymnosperms; they are borne, commonly four together, upon STAMENS, which are usually more specialized structures than the microsporangiate scales of Gymnosperms. The ripe pollen grain contains cytoplasm with but two nuclei, representing

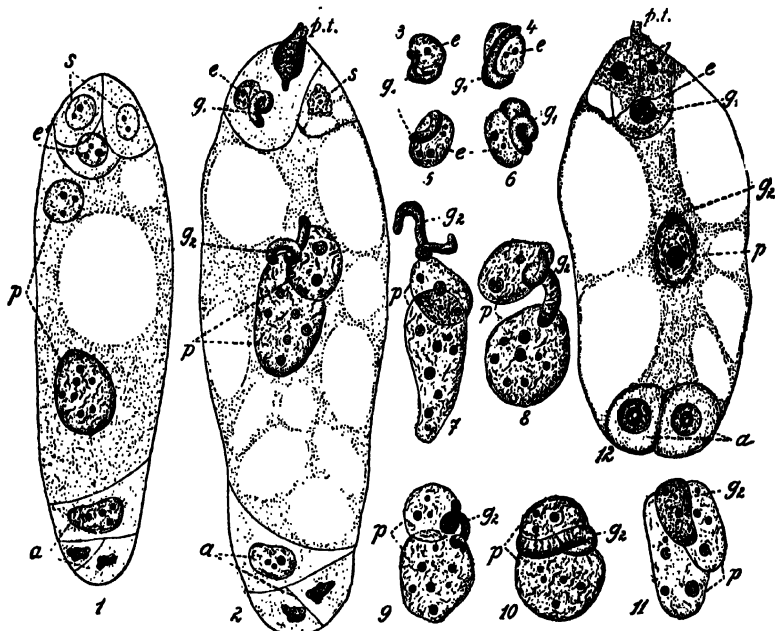


Fig. 224.—Fertilization in Angiosperms

1-11, *Lilium Martagon*. 1, An almost ripe embryo-sac. 2, Fertilization and triple fusion. 3-11, Details thereof. 12, *Ranunculus Cymbalaria*. Fertilization. a, Antipodals; p, polar nuclei; e, egg-cell; s, synergids; p.t., pollen-tube; g₁, g₂, male gametes. All highly magnified.

“tube” and “generative” cells (cp. *Pinus*). At germination the contents pass into the pollen tube; while the tube cell controls the growth of the tube, the generative cell divides to form two male cells.

FERTILIZATION

When the pollen tube enters the embryo-sac one male gamete fertilizes the egg-cell, while the other fuses with the polar nuclei (fig. 224, 2-11). The product of the fertilized egg is the embryo; the other fusion gives rise to the feeding tissue called the ENDOSPERM, which is destined to be absorbed by the embryo either during the ripening of the seed or later during its germination. This “double fertilization” or “triple fusion”, first described about ten years ago by Nawaschin for the Turk's Cap Lily (*Lilium Martagon*), is now known in over sixty species, representing a score of families, and may be universal among Angiosperms.

It is a measure of economy, inasmuch as the laying down of a feeding tissue (the endosperm) in the embryosac is made to depend upon the formation of an embryo which can make use of the store of food.

Very often the pollen tube has to travel a long way from stigma to egg-cell, especially when a *STYLE* is developed which raises the stigma above the ovary; its course is nevertheless usually very direct, mainly owing to the presence of a special guiding tissue. It is interesting to note that a few cases in which the tube follows a less direct path (*e.g.* Elm or Alder), or branches considerably (*e.g.* Birch), occur in families which upon other grounds are believed to be primitive.

POLLINATION—THE FLOWER

One of the most important features of the Angiosperm is the *FLOWER*. A typical flower comprises the following parts, crowded on to a *RECEPTACLE* and forming a fertile shoot: in the centre, a number of carpels; around these a number of stamens; and outside these again a double set of sterile appendages, the perianth-leaves. The inner perianth-leaves or *PETALS* (corolla) are brightly coloured and often also scented, and make the flower conspicuous; the outer *SEPALS* (calyx) are generally green, and serve in the first instance to protect the other parts while the flower is in bud. In addition, some part of the flower generally acts as a *NECTARY*, in which a sweet juice (nectar) is produced. The typical flower is an apparatus for the transference of pollen (pollination) by means of flying insects from the stamen of one flower to the stigma of another (cross-pollination).

Primitive flowers have an inconspicuous perianth, or none at all. Their parts are numerous, arranged spirally upon a relatively long receptacle, and "free" from one another—that is, each develops according to its own laws of growth with little regard to neighbouring parts. In the higher flower-types the various parts are present in definite and usually small numbers and are condensed into cycles (whorls), and altogether spread over a smaller area. Moreover, parts of the same cycle are often "fused"; that is to say, they grow up jointly in the form of a single structure after a certain stage of development; a similar "fusion" may take place between members of different cycles (as, for instance, between stamens and corolla), or the whole margin of the receptacle may be raised up into a cup-shaped structure, or may form a vault completely roofing over the ovary. Elaborate flowers are often divisible into equal halves only in a single plane (zygomorphic or dorsiventral flowers), whereas more simple flowers are generally symmetrical in many planes (actinomorphic or radial flowers).

The meaning of these differences between lower and higher flower-types becomes partly clear when we understand that the general trend of floral evolution has been towards a more perfect adaptation to particular flying insects, and especially to the more powerful, intelligent, or methodical tribes, such as the bees, humble bees, and wasps (Hymenoptera), and the butterflies and moths (Lepidoptera). A delicate mechanism is more readily

built up when a small number of parts arise close together and develop in co-operation with one another from an early stage than when a great number of elements are spread over a large surface and allowed to grow up independently of one another. In cup- or tube-shaped flowers the nectar,

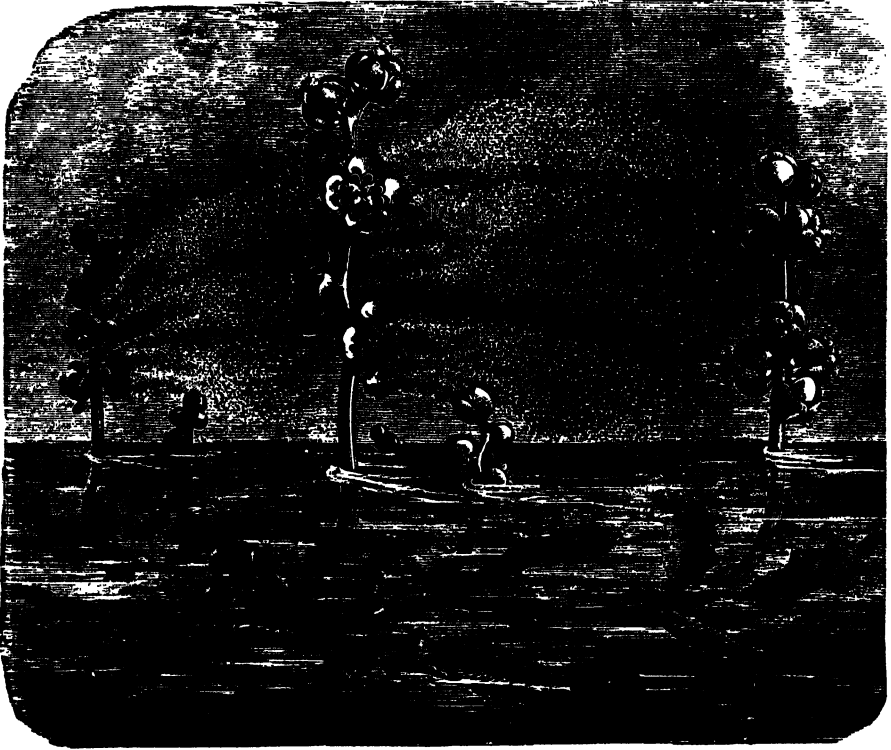


Fig. 225.—Wind-pollination in a Pondweed (*Potamogeton crispus*)

Transport of pollen by wind, which is the rule in Gymnosperms, is not uncommon among the primitive Angiosperms, and occurs less frequently as a secondary adaptation (reduction) in the higher families. The figure also illustrates dichogamy (see text). The shoot on the extreme right is in the "stigma stage": the lower flowers of the left-hand shoots are in the "anther stage".

which is the attraction offered to most insects, can be hidden from unsuitable visitors, while zygomorphy usually forces the insects to enter the flower by a particular "door".

EXAMPLES OF FLORAL MECHANISM

The Plate shows a very small selection from the large number of flowers which have been studied in detail from the point of view of pollination. One of the Sages (*Salvia* sp., Plate, fig. 10) may serve as an example of a moderately complicated mechanism. This flower is pollinated by humble bees. The corolla consists of a gaping two-lipped mouth and a nectar-containing tube; the narrow opening of the latter is closed by the two stamens, which are attached to the corolla and have a very unusual

form, recalling a lever or hammer. When a humble bee probes the tube of a freshly opened flower for nectar, it sets the levers in motion and brings the anthers down upon its back (see fig. 226, which demonstrates the mechanism in another species). When the flower has been open for some time the style bends down and brings the stigma into such a position that it must scrape off the back of a humble bee any pollen which may have been deposited there in other flowers.

The anthers and the stigma are so placed in relation to one another in *Salvia* that self-pollination cannot take place, while a change of position

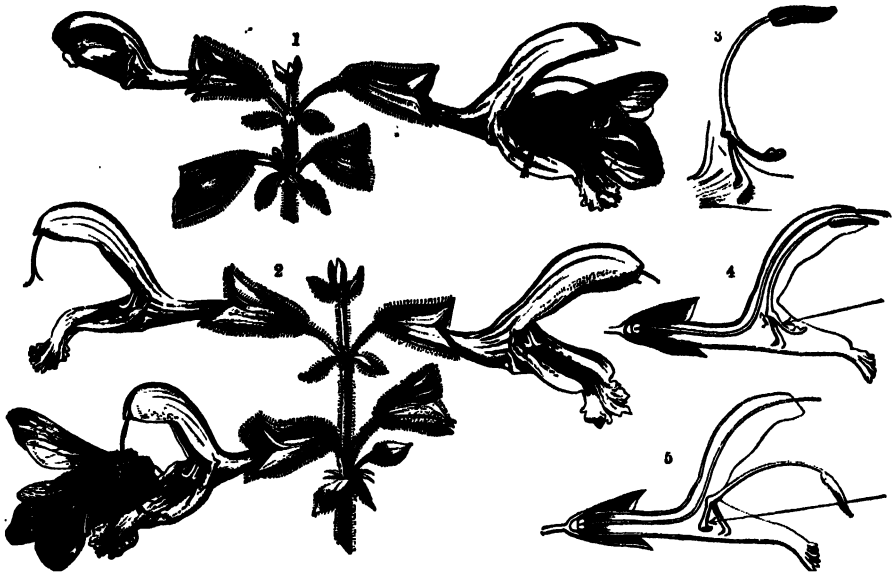


Fig. 226.—Transference of pollen to the bodies of insects by means of mechanism of the percussive type

1, Part of an inflorescence of *Salvia glutinosa*; the right-hand flower is being visited by a humble-bee, and the pollen-covered anther is in the act of striking the insect's back. 2, Another part of the same inflorescence with three open flowers in different stages of development: the lower flower on the left-hand side is being visited by a humble-bee which carries on its back pollen from a younger flower and is rubbing it off on to the deflexed stigma. 3, A stamen of *Salvia glutinosa* with rocking connective. 4, Longitudinal section through a flower of the same plant. The arrow indicates the direction in which humble-bees advance towards the interior of the flower. 5, Same section; the lower arm of the connective lever is pushed backward, and in consequence the pollen-covered anther at the end of the other arm of the lever is deflexed.

is necessary for cross-pollination. The flower may be said to pass through an "anther stage" and a "stigma stage"; a similar succession is common among flowers, and a difference merely in the time of ripening of anthers and stigma (dichogamy) is a still more frequent means of avoiding self-pollination. It is found, for example, in the Figwort (*Scrophularia*), which is further of interest as an instance of a wasp-pollinated flower. Bee-flowers provide a perch (the lower lip in *Salvia*) for their heavy and deliberate visitors. Certain flowers, however, are adapted to insects which alight only for a moment (*Hoverflies*) or not at all (*e.g.* Hawkmoths). Thus the Speedwells (*Veronica* spp.) are pollinated solely by hoverflies, the Turk's Cap Lily (*Lilium Martagon*) mainly by hawkmoths.

No family has more remarkable floral arrangements than the Orchids

In *Coryanthes* (Plate, fig. 8) there is a bucket full of liquid into which bees push one another in their eager onslaught upon the sweet-tasting juicy tissue which forms the roof of the bucket; the drenched insects cannot fly out of the bucket, but have to crawl out through the narrow overflow spout, and in so doing brush past the stigma first and the anther afterwards. This device of admitting the insect by one door and forcing it to depart by another is somewhat unusual, while the quaint method of closing the front entrance is altogether unique. Quite as remarkable in its way is the mechanism of the genus *Catasetum*. As in most Orchids, the pollen is glued together into a pair of pollen masses (pollinia), which here are attached to a common elastic stalk bearing a heavy and very sticky foot or disc at its other end. This "pollen apparatus" is arranged like a taut

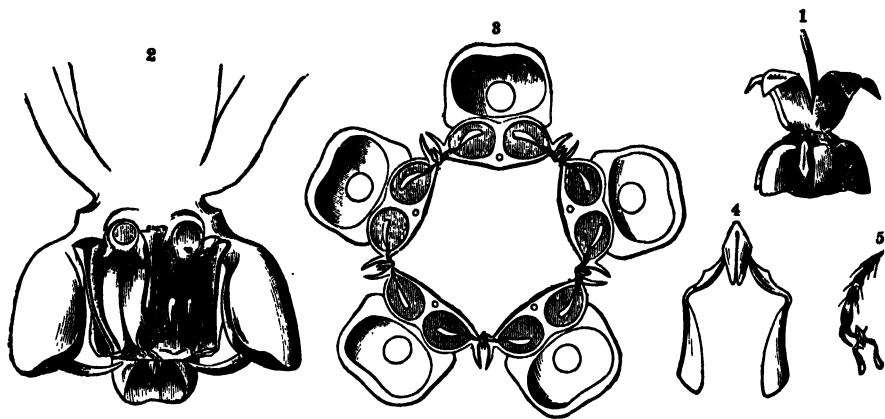


Fig. 227.—Clip-mechanism for fastening the pollinia of *Asclepias Cornuti* to the feet of insects

1, Flower of *Asclepias Cornuti* seen from the side. 2, The same magnified and with two staminal appendages and the front wall of an anther cut away. 3, Transverse section through the same flower. 4, Corpusculum (the clip) with two pollinia. 5, Foot of an insect with pollinia fastened to it by the clip. 1, nat. size; the other figures, $\times 2-5$. A similar arrangement is found in *Horsia* and *Huernia*.

spring, and is "let off" when one of the curious sensitive feelers guarding the entrance to the hollow of the lip—which is lined by juicy tissue—is irritated by a gentle touch or a slight blow. The force of ejection is strong enough to throw the pollen-masses several feet, but a suitable insect visitor receives the disc at short range on the middle of its head, to which it sticks fast. The *Catasetum* flowers of the type just described and figured in the plate have no stigma, and seeds are never set in their ovaries. There are, in fact, separate female flowers, devoid of feelers, sticky disc, or elastic stalk, and possessing imperfect pollen-masses, which are altogether so different in appearance and structure that they were at first placed in a separate genus (*Monachanthus*); in these the stigma is so placed that it cannot fail to be touched by pollen-masses attached to the head of a visiting insect.

The presence of a prolongation of the receptacle in the middle of the flower (the "column"), to which anther and stigma are fused, and the cohesion of the pollen into pollen-masses, are very important features of the Orchid flower; both occur again in the Swallowworts (*Asclepiadaceæ*),

a family which has no close affinities with the Orchids. The curious pinch-trap arrangement for the removal of the pollen-masses, characteristic of this family, is sufficiently explained by fig. 227. The family is interesting also because it includes a number of flowers (especially the species of *Stapelia*, *Huernia* [Plate, fig. 3], and allied genera) which have the appearance and smell of decaying flesh, and are pollinated by carrion-loving flies. In *Stylidium* (Plate, fig. 7, fig. 232, 6a, b) the anthers and stigma are also attached to a column; the latter is slender and flexible and acts like a spring, throwing a shower of pollen over the insect that releases it (see also below, fig. 232). Grass of Parnassus (Plate, fig. 13) has what is known as a deceptive flower; the branched scales alternating with the stamens bear at their ends glistening balls which closely resemble drops of liquid, and lead flies and other rather stupid insects to expect a rich supply of nectar, whereas only a little is actually secreted at the base of the scales. In the *Eucalyptus* shown in the plate the very conspicuous stamens entirely take over the share of attraction generally performed by the corolla. It is interesting to note that this arrangement is common only in dry regions; in the flowers of moist climates, on the other hand, there is generally some provision for the protection of pollen against rain and dew.

IMPORTANCE OF SCENT AND COLOUR

Both odour and colouring are of importance in attracting pollinating insects to flowers. Scent can be perceived at great distances, while colour guides the visitors when they have come within close range. In addition, there are often streaks or dots upon the corolla pointing the way to the nectar; such "nectar-guides" are seen, for instance, in the *Salvia* of the plate. The same flower also illustrates the fact that violet and blue tints have a strong attraction for bees and humble bees; similarly, dull browns (Plate, fig. 11) are particularly agreeable to wasps, lurid tints (Plate, figs. 3 and 4) to flies, reds to butterflies, and pure white (Plate, fig. 2) to night-flying moths. White or yellow is the usual colour of flowers with simple mechanisms and exposed nectar, accessible to a variety of insects but usually neglected by the intelligent species which find the "difficult" flowers more profitable.

THE EXTRAORDINARY CASE OF YUCCA

Generally the intercourse between a pollinating insect and a flower is very brief; but in a few cases there is a lasting connection between the two. The North American species of *Yucca* (fig. 228) are visited solely by the female of the moth *Pronuba yuccasella*. The insect lays its eggs in the ovary, and then deliberately places a large ball of pollen, which it has collected in another *Yucca* flower, in the funnel-shaped stigma. The grubs devour a proportion of the young seeds, which form their only food; on the other hand, cross-pollination is performed with absolute certainty



Fig. 228.—Transport of Pollen by Egg-laying Insects

1, Branch from the inflorescence of *Yucca Whipplei*; the middle flower open, that beneath it was open the previous night and is now closed again, the rest of the flowers in bud. 2, Single flower of the same plant visited by a moth of the species *Pronuba yuccasella*; the three front perianth-leaves removed. 3, Stigma of *Yucca Whipplei*. 4, *Pronuba yuccasella* flying to a flower of *Yucca Whipplei*. 5, Head of *Pronuba yuccasella* with a ball of pollen held by the coiled maxillary palp. 6, Twig with inflorescence of *Ficus pumila*; the urn-shaped inflorescence (or syconium) cut through longitudinally. 7, Single female flower from the bottom of the syconium of *Ficus pumila*. 8, 9, Stamens of the same plant from the upper part of the syconium. 10, Syconium of *Ficus Carica* full of gall-flowers produced by *Blastophaga*, cut through longitudinally; near the mouth of the cavity is a Fig-wasp (*Blastophaga grossorum*) which has escaped from one of the galls. 11, Syconium of *Ficus Carica* full of female flowers, cut through longitudinally; near the mouth of the cavity are two Fig-wasps, one of which has already crept into the cavity whilst the second is about to do so. 12, Male flower. 13, Long-styled female flowers of *Ficus Carica*. 14, Gall produced from a short-styled gall-flower. 15, *Blastophaga grossorum* escaping from a gall. 16, A liberated *Blastophaga*. 17, The same magnified. 1, 2, 4, 6, 10, 11, 16, natural size; 3, $\times 2$; 5, $\times 20$; 7, 8, 9, 12, 13, $\times 5$; 14, 15, 17, $\times 8$.

by the moth, whereas no seed is set without its help. Similar but more complicated relations exist between some of the Figs, including the ordinary fig of commerce (*Ficus Carica*) and certain gall-wasps (*Blastophaga* spp.).

POLLINATING ANIMALS OTHER THAN INSECTS

Insects are by far the most important of pollen-carrying animals, but flowers adapted to pollination by Birds, Bats, and Snails are also known. The Brazilian *Feijoa* (Plate, fig. 1), for example, is pollinated by birds which feast upon the juicy sweet-tasting petals.

THE FRUIT—DISPERSAL OF SEEDS

The arrangements for spreading and sowing seeds rival flower structures in variety. The carpel, which is an important organ in the flower, is of still greater moment in this connection; for the wall of the carpel or ovary (pericarp) usually becomes modified after fertilization has occurred, in the interests of seed dispersal. The resulting structure, known as the FRUIT, is quite as distinctive of Angiosperms as the Flower.

The commonest agents for the dispersal of seeds and fruits are wind and animals. Actual distribution by movements of fresh water is rare; many freshwater and marsh plants have seeds or fruits which can float, but these are generally carried on the plumage of birds or in the mud which sticks to their feet. Ocean currents are the sole means of transport for most shore plants.

DISPERSAL BY WIND

Wind distribution is commonest among plants of savannas, steppes, and deserts, but is also found in tall trees and lianes and in epiphytes. *Spinifex squarrosus* (see above, p. 7) has a round head of fruits about 6 in. in diameter, bristling with long elastic spines, and as light as a ball of feathers; with a gale of wind behind them these heads leap and bound along the shore at a marvellous pace, dropping their grains as they go. In the case of some steppe-plants the whole fruiting plant becomes uprooted and whirled away bodily, and a number of individuals may cling together and roll along in masses as large as a load of hay (the "Wind-witches" formed of *Plantago cretica*, &c.). Usually, however, the single fruits or the seeds are built for rapid skimming through the air (*e.g.* the winged fruits of Ash and Elm), or enabled to float for a long time by means of parachute attachments (*e.g.* fruits of Dandelion or Thistle and seeds of Willow or Cotton).

DISPERSAL BY ANIMALS

About one-tenth of all Angiosperms have hooked or barbed fruits, which can cling to the hairy coats of quadrupeds. Fruits which are fleshy when ripe are devoured by birds, and the seeds ejected unhurt, usually some distance away from their place of origin. Many small seeds, for instance those of the Violets or of the Greater Celandine (*Chelidonium majus*), have curious fleshy crests. The recent work of Sernander leaves no doubt that these outgrowths are attractive to ants, and that a very active dispersal of such seeds takes place along ant-tracks.

EXPLOSIVE FRUITS—VARIETY IN THE STRUCTURE OF FRUITS

Fig. 229 shows two examples of "explosive" fruits or seeds. In the Squirting Cucumber (*Echallium Elaterium*) the wall of the ripe gourd is in a state of great tension; at the moment of ripeness the fruit breaks away from its stalk, and through the hole so produced the contained pulp



Fig. 229.—Sling-fruits

1, *Echallium Elaterium*; branch bearing flowers and fruits. 2, A fruit detached from its stalk and with its seeds squirting out. 3, *Oxalis Acetosella*; entire plant with one unripe fruit on a hooked stalk, and one ripe fruit on an erect stalk ejecting its seeds; nat. size. 4, Unripe fruit of *Oxalis Acetosella*; $\times 6$. 5, Ripe fruit of *Oxalis Acetosella* ejecting the seeds; $\times 6$.

and seeds are violently expelled by the sudden contraction of the wall. Slings, depending upon a similar principle, are found in a number of dry fruits and in some seeds (e.g. the Woodsorrel, fig. 229, 3-5).

In a short space it is impossible to give a true idea of the enormous variety in the structure of fruits; the same plant even may have more than one method of spreading its seeds. The various Dock (*Rumex* spp.) figured below (fig. 230) show very well how the fruit arrangements may be related

to several agents of distribution, and how in a set of allied species a gradual modification of structure takes place in accordance with special adaptation to one of these agents.

It is also important to remember that the "object" of dispersal is

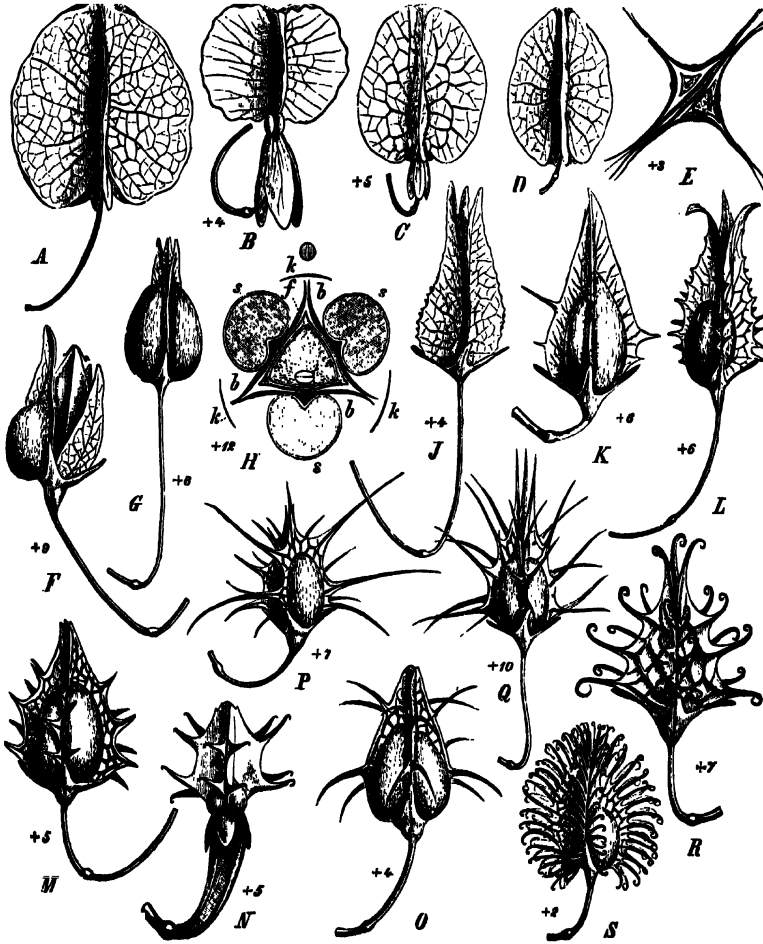


Fig. 230.—Dispersal-mechanisms in various Docks (*Rumex*, spp.)

The most important part of the fruit is here the inner whorl of the perianth-leaves, an exceptional case. Wing-like developments of these (especially A-D) serve for wind-carriage. Spongy "weals" (F, G, L, M, &c.) act as floats for water-transport; in N the stalk is inflated. Spines or hooks (L, N, P, R, &c.)—sometimes assisted by the hooked stalk or the outer perianth-leaves—effect attachment to animals. A species such as A is purely wind-distributed; G is built solely for floating; R is a "burr" and nothing else. The rest show very various combinations of the different methods of dispersal.

not so much removal to a great distance as transport to a suitable spot at the right time. Many features of fruits and seeds are concerned with the protection of the unshed seeds from damp, or with the anchoring of the seeds after their journey.

STRUCTURE OF THE PLANT BODY IN ANGIOSPERMS

While the adoption of insect-pollination and of precise methods of seed-dispersal have no doubt been of prime importance in raising Angiosperms to their present commanding position, a number of other factors have also contributed to their success. The outward form and arrangement of parts in the plant body is extraordinarily varied, in accordance with the fact that Angiosperms are the ruling plants practically everywhere on land and in fresh water and have gained a slight foothold even in the sea, where all

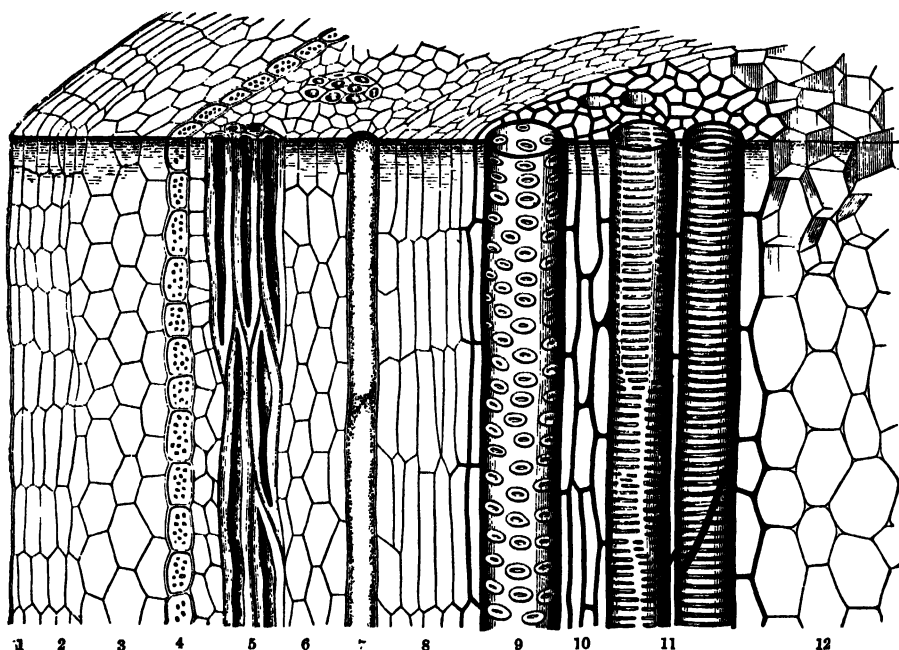


Fig. 231.—Portion cut from a Branch of a Dicotyledon; \times about 200. Diagrammatic

- 1, Superficial coat (Epidermis). 2, Cork (Periderm). 3, Cortical parenchyma. 4, Vascular bundle sheath. 5, Hard bast (strengthening fibres). 6, Bast parenchyma. 7, Sieve-tubes. 8, Cambium. 9, Pitted vessel. 10, Wood-parenchyma. 11, Scalariform and spiral vessels. 12, Medulla or pith.

other Higher Plants are absent. Nearly all these diverse types of plant body are made up of leaf, stem, and root, the three members which are also found in Gymnosperms and Vascular Cryptogams. The internal structure also differs from that of the other Vascular Plants in degree rather than in principle. The greatest complexity on the whole is found in the leaves, which are the main laboratories of the plant. Fig. 231 gives a very diagrammatic view of the chief tissues in the young twig of a tree. At a later stage of development a more elaborate structure would be found, owing to the activity of the dividing layer known as the CAMBIUM, lying between wood and bast, which throughout the growing season adds new cells on both sides; not only is the bulk of the stem increased in this way, but the "secondary" tissues are even more varied than the

"primary". This "secondary thickening" is characteristic of stem and root in one great section of the Angiosperms (the *Dicotyledons*) and in Gymnosperms; exceptional in living Pteridophytes, it was quite common among the extinct Calamites, Sphenophylls, and Lepidodendrons.

SENSE ORGANS

Special attention may be drawn to the structures which are believed to serve as "sense organs". The lens-like organs of leaves, mentioned in a previous chapter, are illustrated below (fig. 232, 1, *2a* and *b*) Sensitiveness to TOUCH is familiar in the case of the "sensitive plant" (*Mimosa pudica*); other instances are the tendrils of the Vegetable Marrow or Bryony, the feelers of Catsetum, the stamens of the Barberry or the Cornflower, and the insect-catching leaves of the Venus' Fly-trap (*Dionaea muscipula*). Haberlandt finds that all such sensitive parts are provided with hairs, pegs, "pits", or similar arrangements, which lead to a local "pinching" of the protoplasm when the organ is rubbed or struck (fig. 232, 3-5, *7a*, *7b*, 8).

GRAVITATION is a factor which is of little ecological importance, because it is so uniform all over the globe, but which, like LIGHT, has a powerful influence upon the position in space of most roots, stems, and leaves. It has been shown by experiment that sensitiveness to gravitation often resides in but a small part of an organ, for example in the tip of a root. The cells in such a sensitive region contain "falling" starch grains, which always place themselves on the physically lower face of the cell. It seems probable that a change in the position of a root with reference to the earth's centre is "notified" to the living substance in the first instance by the change in the lie of the falling starch grains.

While the views set forth above are not accepted in detail by all physiologists, the evidence for the existence of special sense organs in the Higher Plants, especially in Angiosperms, is very strong. It is also quite certain that the place where a stimulus is perceived is often separated from the region which "responds", and that the transmission of the stimulus, which must take place in such cases, is often quite rapid. Nothing, however, corresponding to the nerves of animals is known in any plant.

REVIEW OF PHYLOGENY

It has already been made clear that any attempt to trace the succession in time of the great groups of plants must be largely speculative. The earliest living beings of which we can form any idea may well have been, physiologically at least, like the sulphur- or nitrogen-fixing bacteria, creatures flourishing at high temperatures, indifferent to darkness or to want of oxygen, and otherwise able to cope with violent changes in their environment. Later, some of these primitive beings acquired the habit of photosynthesis. The several groups of coloured Flagellates, and the phylæ of Algæ derived from them, tried different varieties of chromophore and reserve-material. The three great series of Algæ (Green, Brown, and Red) all evolved the many-celled plant body, and advance

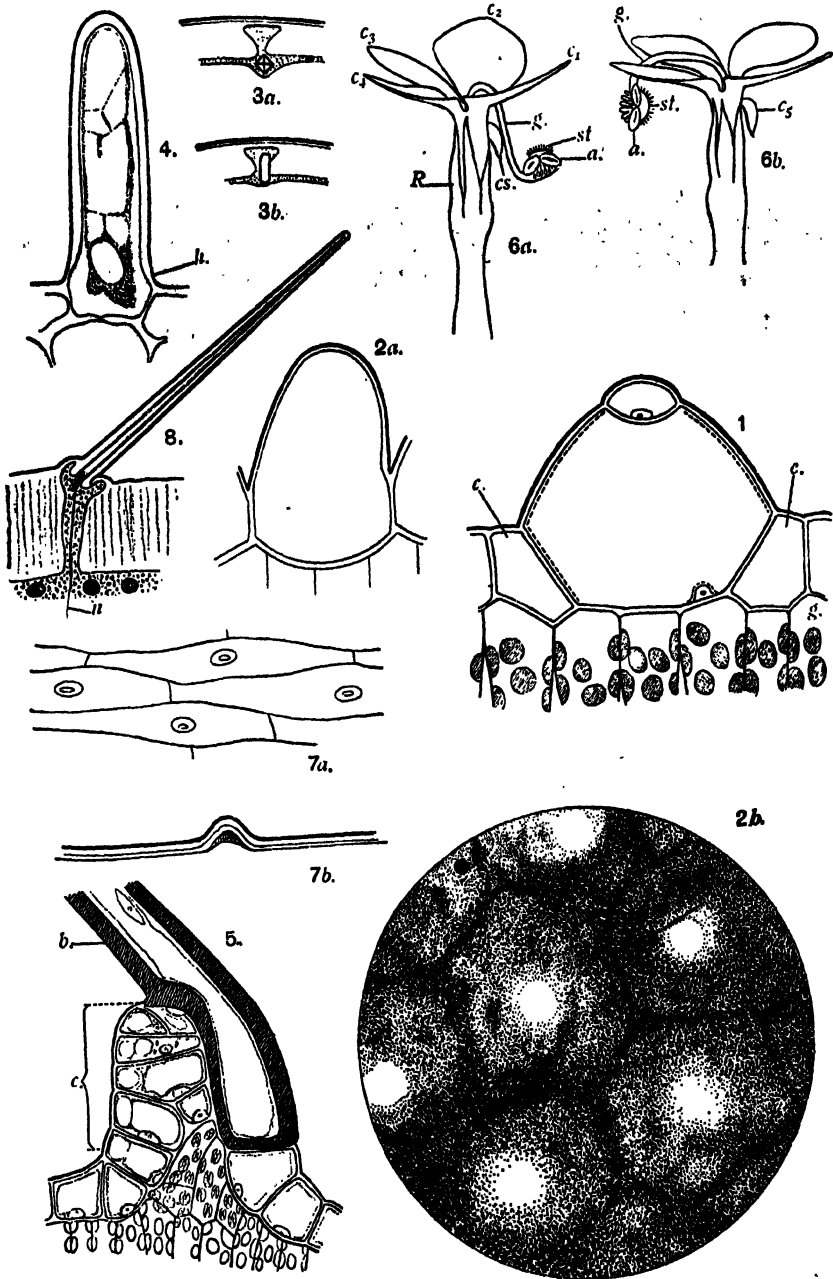


Fig. 232

SENSE ORGANS OF PLANTS

- 1, *Fittonia Verschaffeltii*; vertical section through a light-condensing organ of the leaf; $\times 475$.
 - 2, Ordinary cells of the epidermis. *g*, Green cells with their chromatophores.
 - 2*a*, *Anthurium Warocqueanum*; vertical section through a cell of the leaf epidermis; $\times 210$. Here every epidermis cell is a "lens", with an axis which is slightly oblique, making an angle of 80 degrees with the leaf surface. The fact that the leaf surface itself maintains—by movements of the leaf-stalk—an angle of 80 degrees with the direction of the brightest average illumination strongly supports the idea that these epidermal cells are built to perceive changes of illumination.
 - 2*b*, The same; microphotograph showing the unequal distribution of light upon the inner walls of the epidermal cells. A piece of leaf epidermis was mounted upside down on the stage of the microscope, as a transparent object, and the camera focused upon the inside of the inner cell walls. The theory is that the cells are accustomed to a particular unequal distribution of light (in this case, as in many others, there is a more or less central bright field surrounded by an outer shaded region), any alteration of which acts as a stimulus to heliotropic movement. In this leaf the focus of the cell lens happens to lie exactly on the inner cell wall, so that a sharp image of any object within range is produced. None of the other leaves examined by Haberlandt showed this formation of a sharp image.
 - 3, Touch-pits in epidermal cells of Vegetable Marrow (*Cucurbita Pepo*) in vertical section. The calcium oxalate crystals increase the "pinching" action.
 - 4, Touch-hair from the column of *Mormodes Buccinator*, vertical section; $\times 280$. *h*, Hinge which intensifies the pinch. This Orchid-flower has a mechanism very like that of *Catasetum* (see text).
 - 5, Touch-organ from the sensitive leaf of *Biophytum sensitivum*. When the stout bristle *b* (only the base is figured) is touched, the delicate cells of the cushion, *c*, are squeezed.
 - 6*a*, Flower of *Stylidium adnatum* (somewhat diagrammatic). *g*, Column; *st.*, stigma; *a*, anthers; *k*, calyx; *c*₁–*c*₄, ordinary corolla-lobes; *c*₅, fifth corolla-lobe or "labellum" transformed into a sticky pad to which the column adheres. One-sided growth in the column tends to drag it away from the labellum and ultimately a sudden separation takes place (6*b*), either spontaneously or by the touch of an insect. In *S. adnatum* there is no actual touch-sensitiveness, but a merely mechanical trigger arrangement.
 - 7*a*, A few cells from the column of *Stylidium graminifolium* in surface view, showing pits.
 - 7*b*, A pit in vertical section. The presence of such pits suggests that in this species there is true sensitiveness to touch.
 - 8, Touch-hair of an insect (*Rhapigaster griseus*) for comparison with the plant organs. *n*, Nerve.
- All figs. magnified.

sexual reproduction—into the origin of which we cannot enter here—to a high stage of perfection. The Brown and Red lines flourished best in the sea; but in fresh water the green type of Alga soon asserted its supremacy, and all the Higher Plants are probably derived from ancestors of this kind. As Gymnosperms are known from Silurian rocks, the great invasion of the land which started the evolution of the Higher Plants must have taken place very early indeed.

The Mosses and Liverworts are two "blind" side branches, representing as it were the efforts of the sexual generation to adapt itself to life on



Fig. 233.—*Rafflesia Padma*, parasitic on roots upon the surface of the ground

land. Only Anthoceros seems to abandon the attempt and to fall into line with the Vascular Plants, in all of which the asexual generation has taken over command. As explained above, some botanists believe that the sporophyte was a new development which arose in the early Arche-goniatites, because it was an advantage to these primitive land plants to produce a large number of asexual spores as a set-off against the increased difficulty of sexual union. Others suppose that the succession of asexual and sexual phases, which has been shown in some Green Algae (also in certain Fungi) to depend entirely upon variations in external conditions, became moulded into a regular alternation of generations under the influence of regular changes in the environment, such as might be experienced by amphibious plants. It is quite clear that the sporophyte, when once evolved, was far more at home on dry land than the sexual plant; it soon developed bulky stems and roots (Sphenophyllum, Calamites, Lepido-

dendron), or large leaves (Botryopterideæ), and a complicated internal structure, notable especially for well-developed water-conducting tissue.

An advance of the first importance was the evolution of the seed from the comparatively slight opportunity given by heterosporry. This matter and the equally interesting origin of the pollen-tube have been sufficiently discussed above. It has also been made clear that in the Coal Age seed-bearing plants, namely Pteridosperms and Gymnosperms, were even more conspicuous than the giant Club-mosses and Horsetails.

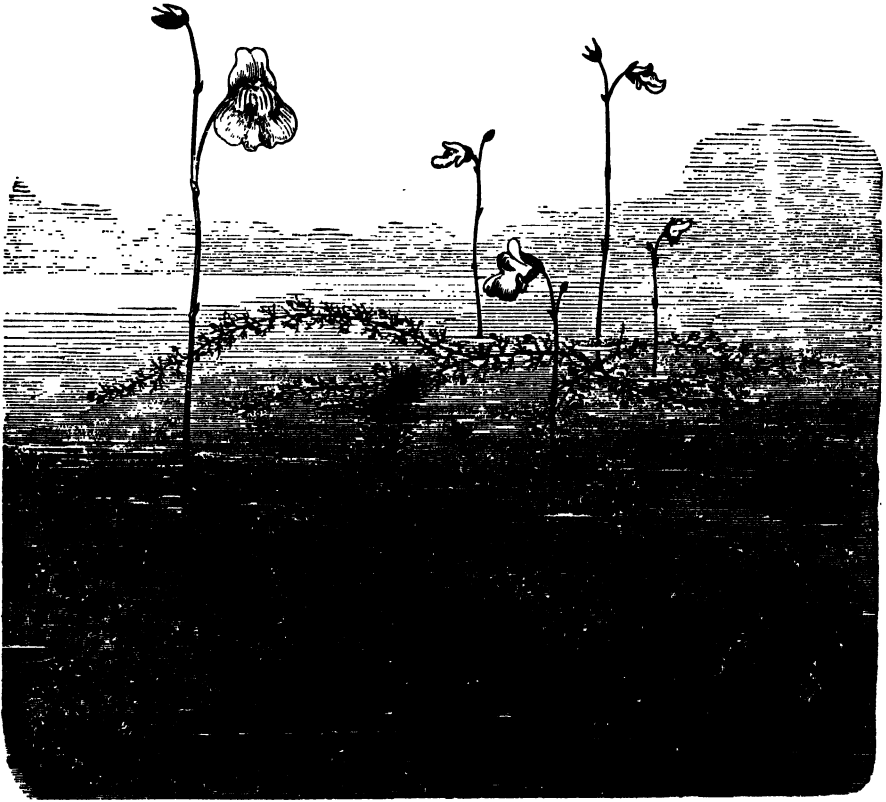


Fig. 234.—Bladderworts

In the foreground, *Utricularia Grafiana*; in the background, *Utricularia minor*.

The Mesozoic period was characterized by its wealth of Cycad-like plants. The most remarkable of these were the BENNETTITALES, a group which has not been mentioned before, because it is interesting to us mainly in connection with the last great problem of plant phylogeny, namely the ancestry of Angiosperms. The Angiosperms appear suddenly in Cretaceous times, and become almost at once the dominant group. We had practically no clue to their affinities until the recent publication by Dr. Wieland of his researches upon American fossil Cycads. From these it appears that the very complicated cones of the Bennettitales bore some resemblance to Angiosperm flowers, the same cone containing

not only ovules, but also numbers of microsporangia borne upon branched structures suggesting modified leaves. It is improbable that Bennettitales were the actual ancestors of Angiosperms, but the two groups probably arose from a common stock.

The stress laid above upon the importance of insect pollination among Angiosperms is further justified by the fact that nectar-sucking insects are almost unknown below the Cretaceous level.

We know that some plants have turned back from the road followed by the majority. The most important among these, of course, are the Fungi, which in the first instance comprised various Algae that had given up photosynthesis. These original Fungi then developed further on their own lines. Such parasites and saprophytes as occur among Higher Plants show a simplification of structure comparable to that of Fungi. An extreme case is that of *Rafflesia* (fig. 233). A typical Angiosperm as far as the flower is concerned, this strange plant has its body reduced to a system of fine cell threads, which penetrate the tissues of the host just like a fungus mycelium. A return to life in water also often results in reduction. The Bladderworts (fig. 234) have no roots, and in the development of the shoot the same young part may grow out according to circumstances into a "stem", an assimilating "leaf", or an animal-catching "bladder". The plant body is practically a thallus.

ECONOMIC IMPORTANCE OF HIGHER PLANTS

While the living Mosses and Ferns are of little immediate value to man, the Palæozoic Vascular Cryptogams are highly important, since they effected the enormous storage of solar energy represented by *coal* (see GEOLOGY). The uses of seed-plants have been dealt with in earlier chapters.

PROSPECTIVE DEVELOPMENTS

In conclusion, we may glance at some aspects of Botany which are now comparatively unnoticed, but which promise to attract great attention in the near future.

EXPERIMENTAL MORPHOLOGY.—In contrasting the Higher Plants with the Lower Plants (Chap. VIII), the comparative fixity of the life-history was cited as one of the distinctive features of the former division. Now Klebs, who so brilliantly proved the entire dependence of the reproductive processes in certain Thallophytes upon external conditions, has lately shown that even in the case of the Flowering Plants one can alter the ordinary course of development very considerably by suitably changing the environment. For example, the Common Bugle (*Ajuga reptans*), in the wild state, passes the winter—like many of our perennial herbs (see above, p. 10)—in the form of a rosette; in the spring, this grows out above into an upright flowering shoot and at the same time sends forth below horizontal runners which root here and there, each finally producing a rosette at its free end. By cultivation under various conditions, Klebs was able to modify this "normal" life-history in several ways; thus, by

a particular mode of treatment, a flowering shoot was induced to grow out at the end into a runner which then formed a rosette (fig. 235, 1). Under other conditions again, a runner can be gradually transformed into a flowering shoot, the rosette stage being omitted altogether. Similar results have been obtained in various Angiosperms by Klebs and others.

THE STUDY OF ABNORMALITIES.—There is no definite boundary between such "Experimental Morphology" and the study of abnormal structure. Our last figure presents a few specimens of the anatomy of abnormal plant structures, some of natural origin (insect galls), others artificially induced. The case of *Basidiobolus* (fig. 235, 6) is especially interesting; for here we have a coenocytic structure created in response to definite physical and chemical conditions in a plant which normally consists of ordinary cells possessing each a single nucleus. Again, a detailed study of cases such as that of the apple kernel (fig. 235, 8a, b), in which abnormal and apparently useless outgrowths appear on the cell-walls, might well throw light upon the important question of the origin of the numerous and varied "normal" types of cell-wall thickening. Both these young branches of our science are likely to acquire great practical importance in the future, because they will give to man a larger, or at anyrate a more certain, control over the entire life-history of a plant and over the development of particular structures. The purely scientific value of such studies is already considerable; it would become enormous if by their aid the botanist should be enabled to base his definitions of species upon physical conditions and chemical compounds as well as upon the data of visible structure.

MATHEMATICAL WORK.—There is a branch of research dealing with such matters as the number, arrangement in space, and symmetry of plant structures, which, failing a better name, may be called Mathematical Botany. Though by no means of recent origin, it has from various causes long remained in the background. Its modern tendency may be illustrated by an observation selected from the recent work of Raymond Pearl. The Hornwort (see above, p. 17) is a submerged water plant with branched stems bearing many whorls of leaves. The number of leaves in the whorls varies considerably on the same individual. On any one branch, however, the variability is greatest in the lowest (oldest) whorls and diminishes at first rapidly, then more and more slowly as younger whorls are counted, until the limit of absolute constancy is almost reached. This "law of growth" for the Hornwort is probably a special case of a general physiological law stated by Jennings in the following words: "An action performed (or a physiological state reached) is performed (or reached) more rapidly after one or more repetitions, so that in time it becomes 'habitual'". Evidently we are here confronted with a problem akin to that of *memory*, a subject which at first sight appears to have little to do with Botany. What appeared to be a very dry exercise in statistics has led us on to consider fundamental properties of the living substance and threatens even to involve us in questions of psychology.

The moral is on the whole an acceptable one. Although Botany,

NATURAL AND ARTIFICIAL ABNORMALITIES

- 1, *Ajuga reptans*; flowering shoot made to grow out into a runner. *r*, Roots.
- 2*a*, Hairs from a gall on the Rampion (*Phyteuma*) flower.
- 2*b*, Hairs from an Erineum-gall on the Maple.
- 2*c-e*, Root hairs deformed by growth in concentrated solutions or by transference from air to water.
- 3, *Conocephalus ovatus*. Transverse section through part of a leaf on which water-secreting excrescences have been produced after the normal hydathodes (Vol. III, p. 165) have been killed by painting them with corrosive sublimate.
- 4, Transverse section through part of the "algal zone" of a cycad root. The host plant sends forth hairlike processes into the large air-space which is invaded by Cyanophyceæ Bacteria and other low organisms (not figured). The meaning of the symbiosis is obscure.
- 5, Kohlrabi clumps of *Rozites gongylophora* (Vol. III, p. 170).
- 6, Giant cells with several nuclei formed by *Basidiobolus ranarum* when grown in 10 per cent glycerine solution at 30° C.
- 7, Transverse section through part of a Nematode gall on the root of Enchanters' Nightshade (*Circæa lutetiana*). *g*, Giant cells with several nuclei.
- 8*a*, Part of a "woolly" excrescence in the core of an apple.
- 8*b*, Two cells from one of the filaments of 8*a*, highly magnified, showing peglike thickenings on the outside of the cell walls.
- 9*a*, Abnormal starch grains from a leaf bulb of *Oxalis crassicaulis*. These bulbs are the modified leaves of runners and are produced when the tip of a runner, and all its side branches, are removed. The disturbance of structure extends even to the starch grains.
- 9*b*, Normal starch grains of *Oxalis crassicaulis*.
- 10, Longitudinal section through wood which has formed in a healing wound of a conifer stem (*Abies cephalonica*). At *a*, grain of the normal wood; at *b*, grain along the edge of the wound; at *c*, the characteristic twisted grain in the healed region.

Fig. 1 reduced; the rest magnified

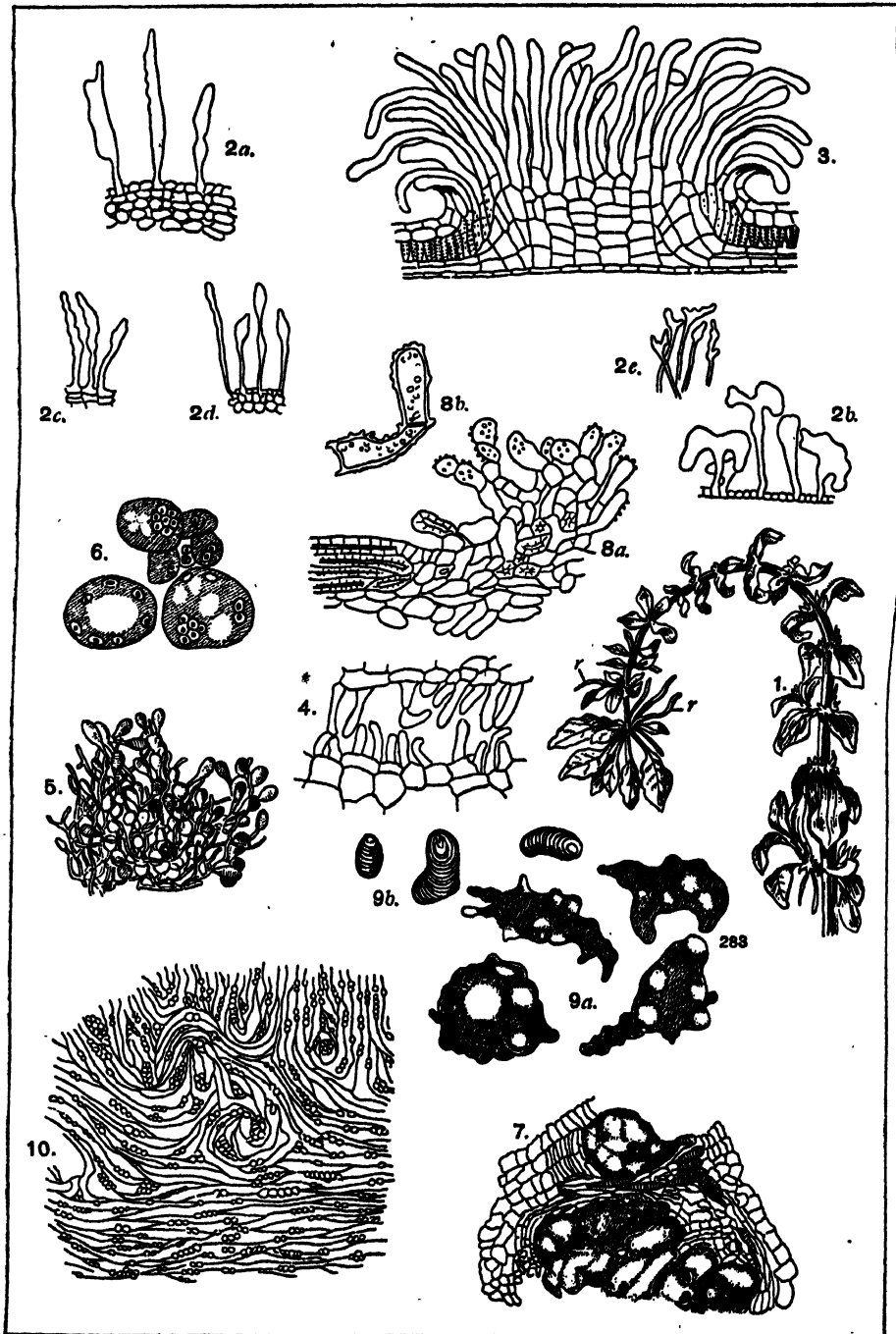


Fig. 235

NATURAL AND ARTIFICIAL ABNORMALITIES

like other sciences, is split up into many special branches, each of them large enough to absorb all the energies of the average investigator, yet these departments are after all not isolated from one another. The unifying principle which can most securely yet flexibly link up the different departments is that which aims at the expression of the results of observation and experiment as far as possible in terms of Chemistry and Physics. The wide acceptance which this ideal is gaining seems to justify the claim put forward in the opening chapter, namely, that a "desire for exactness" is the keynote of modern Botany.

LIST OF WORKS RECOMMENDED FOR FURTHER STUDY

Name.	Author.	Publisher.
<i>General—</i>		
NATURAL HISTORY OF PLANTS	{ Kerner von Marilaun (Translated by Oliver) }	Blackie & Son, Ltd.
TEXTBOOK OF BOTANY ... (The 'Bonn Textbook')	{ Strasburger and others (Translated by Porter & Lang) }	Macmillan & Co., Ltd.
<i>Ecology—</i>		
PLANT GEOGRAPHY ...	{ Schimper (Translated by Fisher & Groom) }	Clarendon Press
EINE BOTANISCHE TRE- PENREISE ... }	Haberlandt	W. Engelmann (Leipzig)
*VEGETATIONSBILDER ...	Karsten & Schenck	Gustav Fischer (Jena)
*HANDBOOK OF FLOWER POLLINATION	{ Knuth (Transl. by Ainsworth Davis) }	Clarendon Press
FERTILISATION OF ORCHIDS	Charles Darwin	John Murray
FORMS OF FLOWERS ...	"	"
CROSS- AND SELF-FERTIL- ISATION }	"	"
NOTES ON THE LIFE HISTORY OF BRITISH FLOWERING PLANTS }	Lord Avebury	Macmillan & Co., Ltd.
<i>Economic Botany—</i>		
THE WORLD'S COMMERCIAL PRODUCTS ... }	Freeman & Chandler	{ Sir Isaac Pitman & Sons, Ltd.
ORIGIN OF CULTIVATED PLANTS }	A. De Candolle	Kegan Paul, Trench & Co.
*HANDBUCH DER TECH- NISCHEN MYKOLOGIE }	Edited by Lafar	Gustav Fischer
<i>Phylogeny and Special Groups—</i>		
*PFLANZEN FAMILIEN ...	Engler & Prantl	W. Engelmann
VORLÄGE ÜBER PFLANZLICHE STAMMESGESCHICHTE ...	{ Lotsy One volume (Thallo- phyta) published }	Gustav Fischer

Name.	Author.	Publisher.
FOSSIL PLANTS	{ Seward One vol. (Flagellata to Sphenophyllales) pub. }	Cambridge University Press
MORPHOLOGIE UND BI- OLOGIE DER ALGEN }	Oltmanns	Gustav Fischer
COMPARATIVE MORPHOLOGY OF FUNGI, MYCETOZOA, AND BACTERIA	De Bary (Transl. by Garnsey & Balfour)	Clarendon Press
ORGANOGRAPHY OF PLANTS	Göebel (Transl. by Balfour)	Clarendon Press
ORIGIN OF A LAND FLORA	{ Bower (Bryophyta & Pteri- dophyta) }	Macmillan & Co., Ltd.
LECTURES ON FOSSIL BOTANY	{ Scott (Vasc. Cryptogams, Pteridosperms and Gymnosperms) }	A. & C. Black

Various—

PHYSIOLOGISCHE PFLAN- ZEN-ANATOMIE ... }	Haberlandt	W. Engelmann
LECTURES ON THE PHYSI- OLOGY OF PLANTS ...	Jost (Trans. by Harvey Gibson)	Clarendon Press
DISEASE IN PLANTS ...	Marshall Ward	Macmillan & Co., Ltd.
PLANT DISEASES	Von Tubeuf (Translated by Smith)	Longmans, Green & Co.
DIE VEGETATION DES BODENSEES ... }	Kirchner & Schröter	J. T. Stettner (Lindau)
THE NEW FLORA OF KRA- KATAU	Ernst (Translated by Seward)	Cambridge University Press
BRITISH FLORA	Bentham & Hooker	L. Reeves & Co.
A FIRST COURSE IN PRAC- TICAL BOTANY ... }	Scott Elliot	Blackie & Son, Ltd.

* Reference Works

ZOOLOGY

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ZOOLOGY

CHAPTER I

HISTORY OF ZOOLOGY

ZOOLOGY, the science dealing with animal life, like the sister subject of Botany, is so vast in extent that its study is subdivided between numerous groups of specialists, whose standpoints are exceedingly diverse. Taking the subject in its broadest sense, the following are among its chief divisions: (1) Animal Morphology, dealing with form and structure; (2) Animal Physiology, concerned with use or function; (3) Embryology, the study of development; (4) Systematics, or Classification; (5) Distribution in space and time; (6) Philosophical Zoology, treating of evolution and kindred topics. Animal Physiology, however, is now considered as a separate branch of learning, although physiological ideas pervade modern Zoology, which without them would lack much of its interest.

FIRST BEGINNINGS.—The foundations of modern Zoology are lost in the mists of remote antiquity, and include the lore of the primeval hunter, the knowledge of domesticated forms subsequently acquired, and the facts gradually accumulated in utilitarian fashion towards the building up of human anatomy and physiology. The stimulus to the imagination afforded by the part animals have played in totemistic practices, ancient religions, and ancient literatures (animal fables, &c.) also had much to do with the rise of the science.

ARISTOTLE.—The first definite point where chaos begins to pass into order is afforded by the work of the great Greek philosopher, Aristotle (385–322 B.C.), whose famous work on the *History of Animals*, revealing an acquaintance with a considerable number of forms, displays a remarkable knowledge of anatomy, physiology, and habits. The position of Aristotle in regard to Zoology has been exaggerated by some, belittled by others, and Huxley is probably right when he says:

“He carried science a step beyond the point at which he found it; a meritorious but not a miraculous achievement. What he did required the possession of very good powers of observation; if they had been powers of the highest class he could hardly have left such conspicuous objects as the valves of the heart to be discovered by his successors” (*Scientific Memoirs*, IV, p. 391).

And again, in regard to the *History of Animals*:

"As a whole, it is a most notable production, full of accurate information and of extremely acute generalizations of the observations accumulated by naturalists up to that time. And yet, every here and there, one stumbles upon assertions respecting matters which lie within the scope of the commonest inspection, which are not so much to be called errors as stupidities" (*loc. cit.*).

To explain these last, however, Huxley suggests that the work in question may, perhaps, consist of the uncorrected notes of students, a class of the community, even now, liable to make the most extraordinary mistakes.

We can also trace back to classical times the knowledge of fossil forms, which has in recent times played such an important part in the development of biological science; while evolutionary ideas are not wanting, though these appear to have been entirely efforts of the imagination.

PLINY.—Only one other classical writer needs brief notice—the elder Pliny—one of the victims of the great eruption of Vesuvius that destroyed Pompeii and Herculaneum in 79 A.D. His large work on *Natural History*, which is by no means limited to the consideration of animals, marks a retrograde movement, but unfortunately his unscientific system of classification by habit met with universal approval, and remained the standard till the sixteenth century.

ENCYCLOPÆDIC PERIOD.—After the break up of the Roman Empire, the entire decay of scientific knowledge of Zoology—among other branches of learning—was in part prevented by the Arabians, but during the dark period of the Middle Ages there is nothing of primary importance to detain us. With later times the name of EDWARD WOOTON (1492–1555), a London physician, deserves mention, as with him began what may be called the "Encyclopædic Period", when Aristotelian methods were revived, and fancy abandoned for fact. We now find elaborate work on individual forms or on groups; a great enrichment of knowledge of the animals of remote countries, due to more extended travel partly stimulated by the discovery of America; advances in classification; and the recognition of "comparative" methods, without which Zoology is a mere jumble of disconnected facts.

Wooton's work *De Differentiis Animalium* (published in 1552) revived and extended the work of Aristotle. Much the same may be said regarding other men of the time, particularly of CONRAD GESNER (1516–65), the first part of whose *Historia Animalium* was published in 1551; and ULYSSES ALDROVANDI (1522–1605), who wrote a voluminous *Historia Naturalium* that began to appear in 1599.

SYSTEMATIC PERIOD.—A period marked by great advances in Classification or Systematics begins with the seventeenth century, one of the most famous names being that of JOHN RAY (1628–1705), whose work was intimately associated with that of his pupil, FRANCIS WILLUGHBY (1635–72). He published an ornithology in 1676, and a Synopsis of Mammalia and Reptilia in 1693, the principles of classification being laid down in the latter. Ray thus helped to prepare the way for his better-known and more famous successor Karl von Linné, commonly called LINNÆUS

(1707-78), in whose great work *Systema Naturæ* (first edition 1735) something like order was introduced into the chaos resulting from the gradual accumulation of innumerable facts. Linnæus initiated the practice of giving a double name to each form, the first being that of the genus, and the second that of the species. The daisy, for instance, was called *Bellis perennis*, and the horse *Equus caballus*. The fault of his system lies in its "artificial" nature, characters selected in an arbitrary way forming the basis of classification, with the result that closely related forms are sometimes separated, and obscurely or distantly related ones brought together.

The seventeenth and eighteenth centuries, however, mark many advances besides those made in classification, though the systematics of a given period are a useful index to current knowledge. A powerful stimulus was given in the former century by the foundation of important scientific societies, regarding which Sir Ray Lankester makes the following remarks (*Advancement of Science*, p. 298):—

"The first founded of surviving European academies, the *Academia Naturæ Curiosum* (1651), especially confined itself to the description and illustration of the structure of plants and animals; eleven years later (1662) the Royal Society of London was incorporated by royal charter, having existed without a name or fixed organization for seventeen years previously (from 1645). A little later the Academy of Sciences of Paris was established by Louis XIV. The influences of these great academies of the seventeenth century on the progress of Zoology was precisely to effect that bringing together of museum-men and the physicians or anatomists which was needed for further development."

IMPROVEMENT IN TECHNIQUE.—The progress of science indicated by the establishment of academies in various countries had an important influence upon Zoology by way of bettering existing methods of observation, more particularly as it led to successive improvements in the compound microscope. The two most famous of the earlier observers to add to knowledge by means of this instrument were ANTON VON LEEUWENHOEK (1632-1723), who discovered the animalcules that swarm in putrefying infusions, besides finding out many other things about the lower animals, and MARCELLO MALPIGHI (1628-94), Professor of Medicine at Bologna, who laid the foundations of our knowledge of the minute structure of higher forms. The same good service was rendered by the illustrious HARVEY (1578-1657)—best known as the discoverer of the circulation of the blood—to the science of embryology, for he described the development of the chick. But this branch of Zoology was much further advanced by CASPAR FRIEDRICH WOLFF (1735-94), who in his great work *Theoria Generationis* (published 1759) proved that the complex body of a higher animal results by a gradual process of upbuilding ("epigenesis") from a simple germ, and not by a mere increase in size ("evolution" in the old sense) of parts already present from the beginning.

NATURALISTS.—The period which witnessed so much activity in systematics, and in what may be called "laboratory" branches of Zoology, also produced a number of observers, more or less eminent, who took

particular pleasure in studying the habits and life-histories of animals, who were, in fact, what we should now call "naturalists". One of the greatest of these was SWAMMERDAM (1637–80), who made many observations on lower forms, and described the life-history of the frog. During the eighteenth century this kind of activity was carried on by such men as Réaumur, Rösel von Rosenhöf, De Geer, Bonnet, Trembley, and Gilbert White. KÜLREUTER (1733–1806) and SPRENGEL (1750–1816), especially the latter, laid the foundations of our knowledge regarding the relations between flowers and insects.

NATURE PHILOSOPHY.—In the eighteenth century, too, we note the rise of a school of "Nature Philosophy", of which BUFFON (1707–88) was a chief exponent, and which realized in a dim speculative fashion, under the name "unity of nature", the actual relationship between different forms which is an axiom of the modern evolutionary school. Buffon was the first zoologist to observe that species vary, or to reflect on the problems presented by the geographical distribution of animals. CHARLES BONNET (1720–93) and ERASMUS DARWIN (1731–1802) belonged to the same school.

PERIOD OF MORPHOLOGY.—The beginning of the nineteenth century broadly corresponds with the initiation of a period of Morphology, marked by a thorough study of form and structure, and increasing attention to the comparative method. It represents in part a reaction against the artificial systematics of the Linnæan school, and its foundations were laid by the labours of such men as JOHN HUNTER (1728–93). The one name that stands out prominently here is that of CUVIER (1769–1832), who first placed "natural" as opposed to "artificial" classification on a firm basis, and recognized four main types or "general plans of structure on which the respective animals appear to be modelled, and whose individual subdivisions, as they may be called, are only slight modifications based on the development or the addition of some parts, without the plan of the organization being thereby essentially changed" (Claus's *Elementary Text-book of Zoology*, Eng. trans., p. 136).

Cuvier's great ability, immense knowledge, and powerful influence enabled him to establish his views at the expense of the Nature Philosophy school, as represented more especially by LAMARCK (1744–1829), ST. HILAIRE (1772–1844), GOETHE (1749–1832), and OKEN (1779–1851). This was an advantage by way of checking undue speculation and furthering the accumulation of facts, but retarded the progress of legitimate theory, and created a tradition that required the genius of a Darwin to overthrow. Fortunately, however, Cuvier realized the importance of fossil forms, and did much to render modern palæontology (*i.e.* the study of fossils) possible. Among the more distinguished men who carried on the Cuvierian tradition were JOHANNES MÜLLER (1801–58) and RICHARD OWEN (1804–92), to whom HUXLEY (1825–95) would probably have been added had he not been profoundly influenced by the Darwinian hypothesis.

CELL THEORY.—A notable characteristic of the period was the elaboration of the "cell theory" by SCHLEIDEN (1838) and SCHWANN (1839), which, taking the cell as the unit of structure and function, has proved a

most fertile conception, as already set forth in the section on GENERAL BIOLOGY, to which much will be added in that on PHYSIOLOGY AND MEDICINE. Nor must we forget the work of VON BAER (1792–1876) and VON KÖLLIKER (1817–1905) in the domain of embryology. Important researches in other directions were also made by numerous men of distinction, but the exigencies of space forbid details.

The PERIOD OF EVOLUTION in which we now live, and which concludes this necessarily brief sketch, commenced somewhat sharply on the 1st of July, 1858, when papers were read by CHARLES DARWIN (1809–82) and ALFRED RUSSEL WALLACE (born 1822, and happily still with us) enunciating the theory of Evolution by Natural Selection, dealt with in the section on PHILOSOPHICAL BIOLOGY. Darwin was led to his conclusions by observations made in South America, and independent views of the same nature were reached by Wallace as a result of his work in the Malay region and the East Indies. It is the proud boast of biologists that these conclusions have not only profoundly influenced their own subject, but revolutionized almost every department of human thought. Their rapid spread was due in no small measure to the vigorous championship of the late Professor HUXLEY, with his unrivalled store of knowledge, and the equally strong support of that brilliant controversialist Professor ERNST VON HAECKEL. Scarcely less is due to the veteran botanist Sir JOSEPH HOOKER or to the late Professor FRANCIS MAITLAND BALFOUR (1851–82), who had established a world-wide reputation for comparative embryology before the close of his brief career.

MODERN THEORY.—During the last thirty years Zoology has advanced with great rapidity in all possible directions. Its theory has been influenced in a remarkable way by the speculations of Professor WEISMANN, and more recently by the long-forgotten work of MENDEL on heredity. The material for research has accumulated to a vast extent, largely on account of the numerous scientific expeditions that have been and are being organized by various countries, by the establishment of marine stations (of which the premier one is at Naples), and by the arrangement of museums on rational lines. The rise of a new palæontology, as laid down by such men as NEUMAYR, VON ZITTEL, COPE, and MARSH, has provided a firm foundation for the study of phylogeny, *i.e.* the evolution and mutual relationship of animal groups whether large or small. Thirty years ago the pedigree of horse-like forms was the only one established with anything like certainty, but now it is one among many.

MODERN TECHNIQUE.—There has also been constant improvement in the methods of laboratory research, especially in the way of cutting thin sections and the perfecting of optical appliances. It is now possible to cut a continuous series of sections of a minute animal or embryo, using the same for reconstruction of an enlarged model. By special methods of staining, details have been discovered which were before unsuspected, and the life-histories of microscopic forms worked out. Such methods have enabled the enormous magnification of the modern compound microscope to be used to great advantage, so as to demonstrate a world of detail within the cell, once regarded as the unit of structure. Investigations of

this nature have played a prominent part in unravelling the complex problems of heredity, while they have also proved of prime importance in the study of disease.

With great ingenuity Sollas has invented a modification of this method by which it is possible to make models of fossils so imbedded in stone that to chisel them out is impossible. In this case the object is gradually ground down, and a series of photographs taken at regular intervals corresponding to a given thickness.

MODERN CLASSIFICATION.—The classification of animals has been profoundly influenced by the advance of zoological science, and approximates more and more to arrangement by actual pedigree, so that modern schemes of classification resemble genealogical trees, which in fact they are. This is what we now mean by "natural" classification. It is rarely possible to any large degree, except in the case of groups possessing hard parts capable of preservation in the fossil state, and which have actually been so preserved in large amount during geological time. We now know, for example, a great deal about the actual affinities of elephants, but can do little more than speculate about the descent of some of the groups of worms in which the body is entirely composed of soft tissues.

NATURE STUDY.—Considerable impetus has of late years been given to what is termed "Nature Study", which may be considered as an extension on scientific lines of the methods employed in a crude form by Gilbert White and his many followers in the pre-Darwinian epoch. It is in effect the study of living animals and their habits, considered as parts of an infinitely complex web of life. In the course of evolution animals have become adapted to various kinds of surroundings (environments), as long since perceived by Lamarck, and any animal (or plant) embodies solutions to a number of practical problems, which if unsolved would have meant complete extinction. Adaptations to swimming, burrowing, flying, to life in the sea, and life in fresh water, all afford good examples. Any particular environment is exceedingly complex, very liable to change, and inclusive of both non-living (*e.g.* climatal conditions) and living factors (local fauna and flora).

Regarded in this way, Nature Study is a subject of school and college education which has great possibilities, turning to good purpose for mental training the natural sympathy man has with nature, and directing into proper channels the craze for "collecting", which has so often meant in the past little but the ruthless hunting down of rare species. In its early stages the subject is mainly useful for cultivation of the powers of observation, and later on brings the "how and why" more into prominence, thus training the reasoning powers in no mean degree. A boy who has received a suitable training in Nature Study will not only have had his mental powers improved, but will be provided with an intellectual "hobby" that may prevent him from becoming a mere business machine, and he will be able to take an intelligent interest in many burning problems of the day, such as the principles of heredity, which, in spite of their important bearing on human progress, are too often regarded as a mere field of debate for scientific experts.

CHAPTER II

PRELIMINARY SURVEY OF THE ANIMAL KINGDOM

As frequent reference will necessarily be made in the sequel to the chief groups of animals, it may be well to speak very briefly of them here.

In fig. 236 a very rough genealogical tree is given of the animal kingdom, each branch of the same corresponding to an important sub-kingdom or phylum. Each such branch subdivides in a more or less complex way, according to the number and nature of the sub-groups of the particular phylum, but such division is omitted for the sake of simplicity. It must be presupposed that actual living matter (protoplasm) exists in the form of minute particles called *cells*, each of which is controlled by a specialized part known as the *nucleus*. Details are given in other sections.

The first forms of life doubtless came into existence by evolution from non-living substance, though how and when we do not know, nor are we very likely

to learn. Such forms were in all probability not very unlike the simplest green plants which now exist, and which are able by means of their characteristic pigment (chlorophyll) to utilize sunlight in building up protoplasm from simple inorganic chemical compounds. Animals have lost this power, with few exceptions, and hence have diverged from the members of the plant realm, which still, in the majority of cases, retain it.

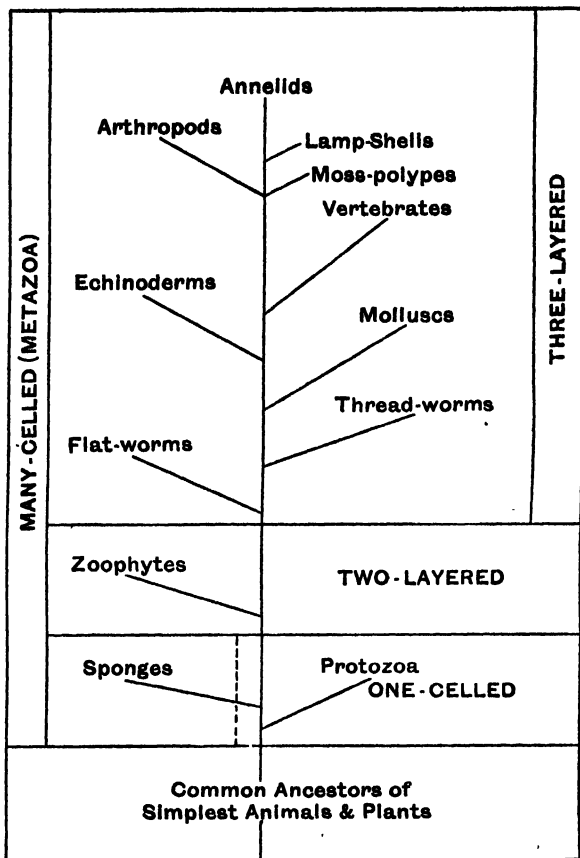


Fig. 236

I. PROTOZOA (ANIMALCULES)

INFUSORIA.—When the Dutch naturalist Leeuwenhoek, inspired by a somewhat dilettante spirit of curiosity, examined drops of putrefying infusions through his crude compound microscope, in the latter part of the eighteenth century, he perceived swarms of little creatures swimming about with the greatest activity, and, on account of the material in which these were first discovered, these are now known as **INFUSORIA** (fig. 237). Some of them progress by means of the whiplike movements of one, two, or a few slender threads of living matter (flagella), and others by the alternate bending and straightening of shorter and more numerous threads of the same material (cilia). Hence a division of infusoria into *Flagellata* (fig. 237, E, F, G, H) and *Ciliata* (fig. 237, B, C). In the more specialized of such forms the food partly consists of solid particles of organic nature taken in through a mouth into the soft protoplasmic body substance, but many flagellates do not require such an arrangement, as they simply absorb the nutritious fluid which serves as their home. A number of infusoria (but not those found in infusions) are fixed to various objects by stalks, their flagella (or cilia) setting up currents by which particles of food are brought.

RHIZOPODA.—In another group of Animalcules (Rhizopoda) the body is not covered by a membrane, and its protoplasmic substance is able to flow out into blunt or it may be thread-like lobes (pseudopods) which differ from flagella and cilia in not being permanent structures (fig. 237). A well-known form is the celebrated Proteus Animalcule (*Amæba*), which pushes out blunt pseudopods from any part of its body, using them for locomotion and the capture of food (fig. 237, R). Some similar types living in fresh water possess a sort of shell (fig. 237, Q).

Very notable are the **FORAMINIFERA** (fig. 237, M, N, O, P) which swarm in infinite numbers on the surface of the sea (and to a less extent on that of fresh water), and are provided with numerous slender radiating pseudopods, and an often complicated, usually calcareous, shell. When these animalcules die their shells rain down upon the ocean floor and accumulate as foraminiferal "oozes" covering vast areas. Similar in some respects are the marine Ray-animalcules (**RADIOLARIA**), with complex siliceous shells, making up other oozes on the floor of much deeper parts of the sea (fig. 237, J).

SPOROZOA.—Far different in character are the Spore-animalcules (Sporozoa), distinguished by their parasitic habit, and the cause of certain fatal diseases, such as "sleeping sickness" and malarial fevers, as we shall learn in a subsequent section (fig. 237, A).

In spite of notable differences a typical animalcule or protozoon, to whatever group belonging, is a simple cell, and the Protozoa are therefore said to be *unicellular*, and probably come nearest to the first animals that ever existed, though many of them are greatly specialized on lines of their own.

METAZOA.—The remaining sub-kingdoms of animals are conveniently lumped together as **METAZOA**, their bodies consisting of aggregates of

PROTOZOA, ENLARGED TO VARIOUS SCALES

- A, Cockroach Gregarine (*Clepsidrina blattarum*).
B, Bell-Animalcule (*Vorticella*) extended and retracted.
C, Slipper-Animalcule (*Paramæcium*).
D, Volvox.
E, Euglena.
F, Noctiluca.
G, Codonocladium.
H, Monads; 1 and 2, Springing Monad (*Heteromita*); 3, *Chilomonas*; 4, *Hexamita*.
J and J', Skeletons of Radiolaria (*Heliosphæra* and *Eucyrtidium*).
K, A Sun-Animalcule (*Actinosphærium*).
L and L', Small piece of a Mycetozoon and two capsules (one ruptured) of same.
M, A Foraminifer (*Rotalia*), with protruded threads of protoplasm.
N, O, P, Shells of Foraminifera (*Globigerina*, *Nodosaria*, and *Miliola*).
Q, A shell-bearing Rhizopod (*Diffugia*), allied to Amœba.
R, Proteus Animalcule (*Amœba*).
Reference letters:—F., Food; FL., flagellum; G., gullet; M., mouth; MAC., macronucleus; MIC., micronucleus; N., nucleus; P.V., pulsating vacuole.

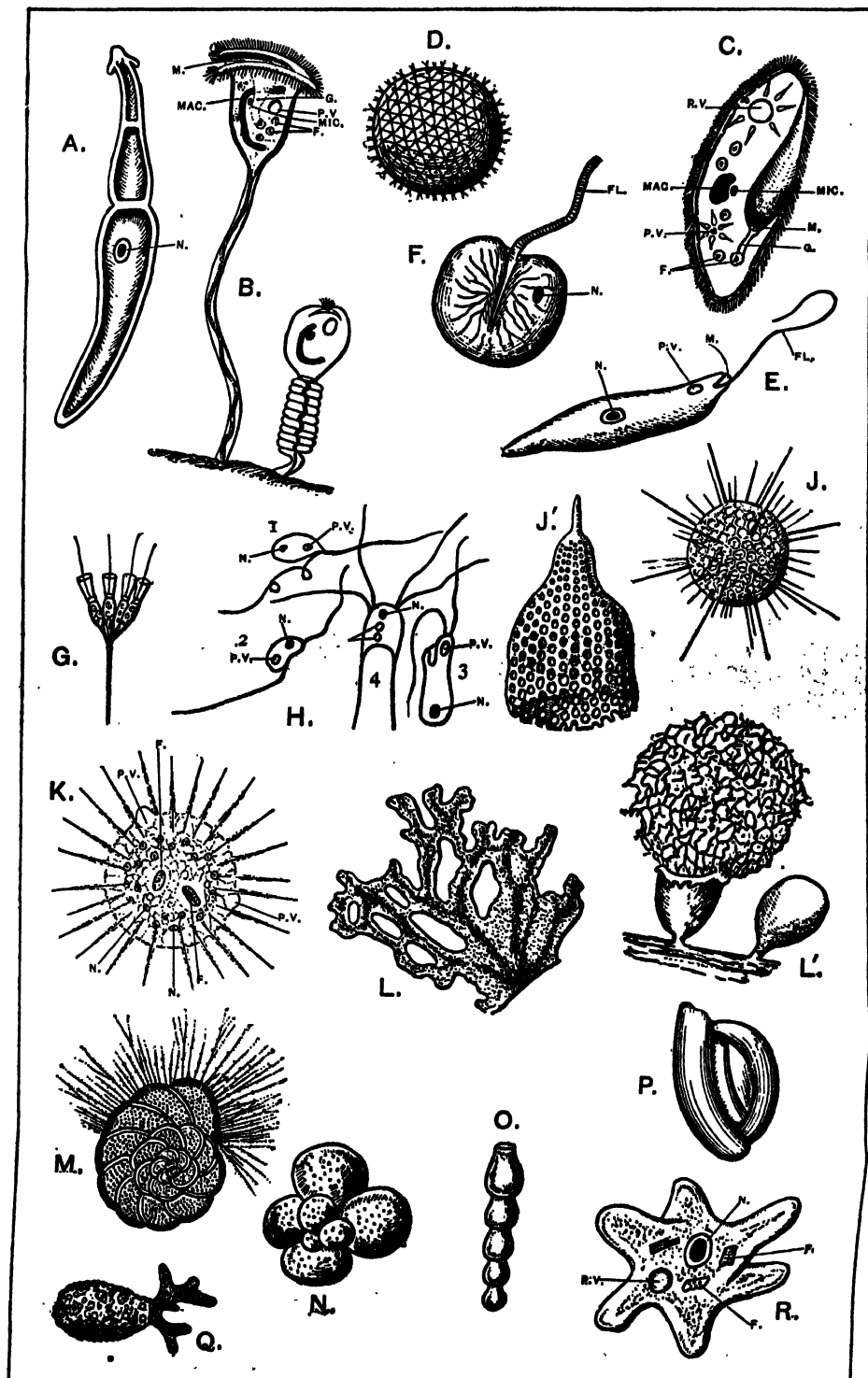


Fig. 237
 PROTOZOA, ENLARGED TO VARIOUS SCALES

cells, *i.e.* they are *multicellular*. In Protozoa there may be more or less "division of physiological labour" between different parts of the same cell, but in Metazoa this sharing of responsibility takes place between different groups of cells, which assume different forms and characters in accordance with their uses. These modified groups are known as *tissues*, and in higher forms include muscle, nerve, and so forth, the differences between which are obvious even to the naked eye. The terms "high" and "low" have reference to the extent to which the division of labour is carried out, marked by a corresponding differentness in structure (morphological differentiation).

ORIGIN OF METAZOA.—There can be no doubt that Metazoa have been derived from Protozoa, though the exact manner of evolution is somewhat obscure. We know, however, that some of the latter are *colonial*, *i.e.* a number of individuals are permanently connected together, and by supposing division of labour between the members of such a colony the origin of Metazoa can easily be imagined. There are indeed certain existing colonial Protozoa in which such a process is beginning (fig. 237, D).

II. SPONGES (PORIFERA)

The familiar bath sponge is the horny skeleton of an animal of this kind, but as it belongs to one of the numerous colonial forms where a number of individuals are closely united together without sharply-marked boundaries, it will be better to consider a simple type (fig. 238). This may be described as a flask- or vase-shaped creature, attached at one end, and with numerous small holes in its wall. If examined when alive, and under natural conditions, it will be found that currents of sea water continually flow through these small holes into the cavity of the vase, and out of its large aperture. As in the fixed Protozoa, the currents serve the purpose of bringing food, promote breathing, and carry away waste products. Microscopic examination of the sponge shows that its hollow body is lined by cells closely resembling

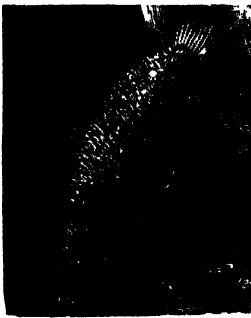


Fig. 238.—A Calcareous Sponge
(*Sycandra raphanus*)

some of the flagellate Protozoa, from which most probably the group has been derived. The wall of the vase is strengthened by numerous sharp needles or spicules of calcareous nature.

Most sponges, however, are very much more complicated than the simple type described, and their colonies assume the most various shapes. The spicules of the skeleton are often siliceous, and may be welded together into a firm mass. Sometimes horny fibres are present in addition, or less frequently, as in the bath sponge, these may entirely replace spicules.

III. ZOOPHYTES (CŒLENTERA)

While sponges represent a special and highly peculiar offshoot from the Protozoa, the animals familiarly known as zoophytes (Gr. *zōon*, animal; *phyton*, a plant), because their branching colonies were formerly mistaken for plants, are probably in the main line of descent of the Metazoa. There are two main subdivisions: (1) Hydromedusae, and (2) Anthozoa.

1. HYDROID ZOOPHYTES AND JELLY-FISHES (HYDROMEDUSAE). — The leading characters of a hydroid zoophyte are represented in fig. 239, where we observe a branching colony covered by a firm horny skeleton expanding into little cups for the lodgment of the individual members (polypes), each of which possesses a central mouth surrounded by a circlet of tentacles by which prey is secured. There is also an egg-producing stage in the form of a minute free-swimming jelly-fish (medusa).

A closer study of the little solitary Freshwater Polype (*Hydra*), devoid of skeleton and jelly-fish stage, will enable us to better understand the lines on which the body is constructed. Here the body is a

tube, with a mouth and circlet of tentacles at one end (fig. 240). The wall of the tube essentially consists of two layers of cells, an outer (*ectoderm*) and an inner (*endoderm*), the latter being primarily concerned with digestion, and the former with protection and control of the activities (*i.e.* it plays the part of a nervous system).

All jelly-fishes are not stages in the life-history of fixed hydroid zoophytes; in fact, there is no fixed stage in the case of the larger animals of the kind which are most familiar to the seaside observer.

2. SEA-FLOWERS (ANTHOZOA). — The Sea-anemones which abound on rocks between tide-marks are in some ways more complicated in

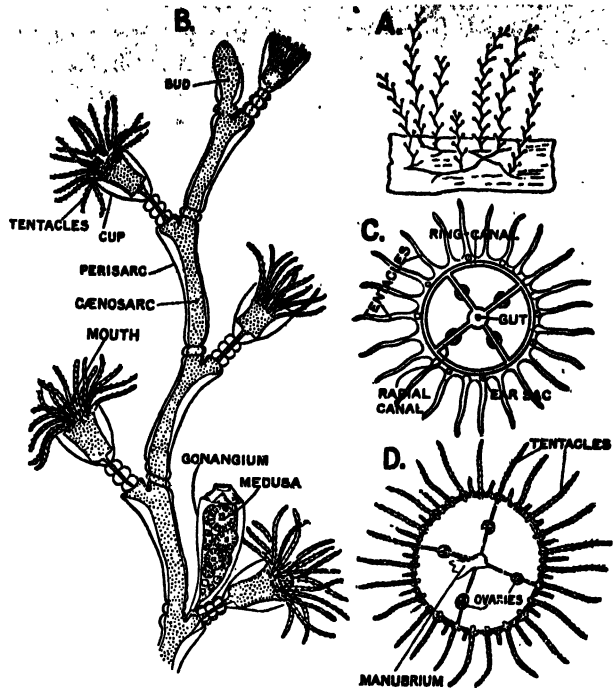


Fig. 239.—Fixed and Free-swimming Stages of a Hydroid Zoophyte (*Obelia*). A, Natural size; B-D, enlarged

A, A colony of the fixed (hydroid) stage, attached to a piece of sea-weed. B, End of a branch of same. C, Upper side, and D, under side of the free-swimming stage (jelly-fish or medusa).

structure than hydra and its allies, as will be gathered by reference to fig. 241. Corals are closely related, but differ in possessing a calcareous skeleton. They may be solitary like the anemones, or colonial, assuming the most various forms in the latter case.

TWO-LAYERED ANIMALS.—The essential feature by which all the Zoophytes, of both groups, are characterized is the possession of two primary layers of cells in the body wall. We may therefore term them two-layered animals, and they represent an early stage in the evolution of

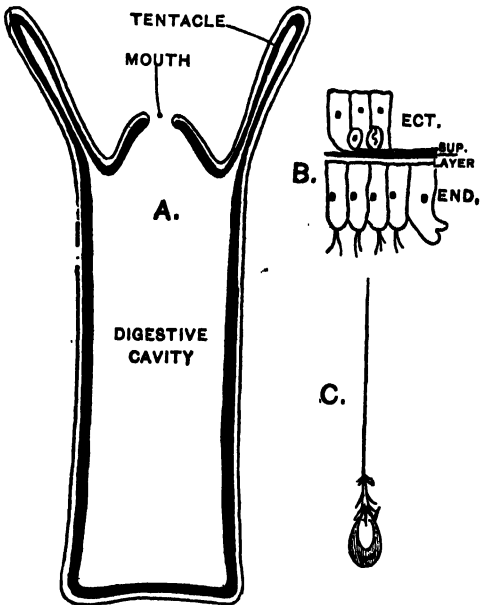


Fig. 240.—Diagrams, enlarged to various scales, illustrating the structure of Hydra

A, Longitudinal section: ectoderm left white, endoderm represented in black. B, Small part of longitudinal section through body-wall (the black dots are nuclei); ECT., three large cells and two packing cells are seen; SUP. LAYER, supporting layer or lamella; END., endoderm, showing four cells with flagella, and one with pseudopodia. C, A netting-cell, with thread protruded—note barbs at the base of this, and the trigger hair on the right side; the protoplasm investing cell is shaded, and the nucleus represented in black.

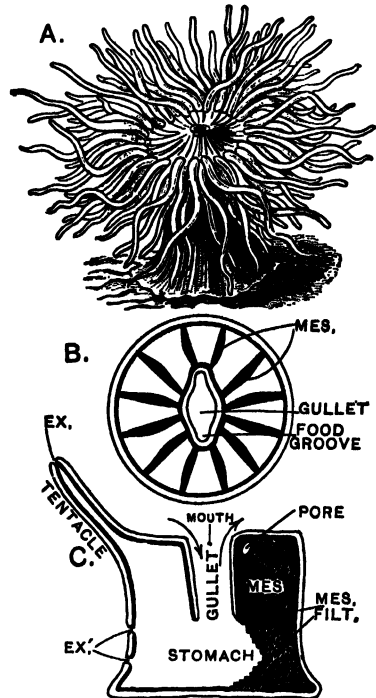


Fig. 241.—Sea-anemone

A, External view of a Sea-anemone (*Anemonia*). B, Diagrammatic cross-section; MES., mesenteries: only one of the two food-grooves is lettered. C, Diagrammatic longitudinal section, showing a mesentery (MES.), with mesenteric filaments (MES. FILT.) on the right, and one of the spaces between two mesenteries on the left; EX., EX', excretory pores: the arrows indicate the course of currents into and out of the gullet along the food-grooves.

Metazoa, where the division of labour between the cells making up the body is but imperfectly effected.

THREE-LAYERED ANIMALS.—All the remaining phyla may be collectively termed three-layered animals, because at an early stage of their individual development a third layer of cells (*mesoderm*) makes its appearance between the two which alone are present in Zoophytes. This means that the division of physiological labour is carried on to a further stage. It may be taken as a general principle that the successive steps in the development of an animal represent in a broad way the evolution of its group (Recapitulation Theory), and, as all three-layered animals pass

through a two-layered stage at an early period of their existence, this may be regarded as an indication of descent in the remote past from forms constructed somewhat on the lines described for *Hydra*.

RADIAL SYMMETRY.—Most Zoophytes are either fixed, or else (jelly-fishes) drift or swim in an indefinite manner. They therefore react to surroundings in pretty much the same way all round, which probably accounts for the star-like arrangement of parts round the central mouth. This kind of regularity is technically known as *radial symmetry*.

BILATERAL SYMMETRY.—The vast majority of three-layered animals, however, progress more or less actively in a definite direction, and in adaptation to this have acquired, as a rule, an elongated form, convenient for swimming, creeping, burrowing, or other ways of locomotion. The re-

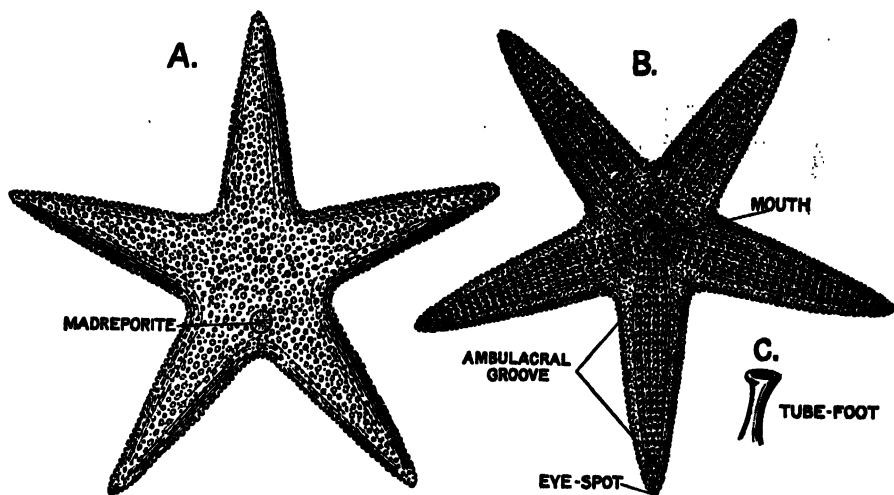


Fig. 242.—Common Star-fish (*Uraster rubens*)

A and B, Upper and under surfaces, reduced; C, a tube-foot, much enlarged.

action to surroundings must necessarily be different at the two sides, in front, behind, above, and below, which is expressed by the two-sided or *bilateral symmetry* that is now characteristic. Such symmetry, in fact, necessarily involves not merely a distinction between right and left sides (mirror images of one another), but between front (anterior) and back (posterior) ends, and upper (dorsal) and lower (ventral) surfaces. This is admirably exemplified by such an animal as an insect, a cockle, or a fish. It should be mentioned, however, that some members of various bilateral groups have reverted to a sedentary or fixed life, and in such cases there is a tendency to reassume a greater or less measure of radial symmetry.

IV. HEDGEHOG-SKINNED ANIMALS (ECHINODERMA)

The existing forms these include are Sea-lilies (and Feather-stars), Starfishes, Brittle-stars, Sea-urchins, and Sea-cucumbers. Of these the stalked Sea-lilies of the deep sea are the only fixed ones. Taking a

common star-fish as the best-known representative of the phylum (fig. 242), we notice at once that it appears to contradict what was said in the last paragraph, for it seems to be entirely radially symmetrical. But if the upper side be examined closely, a curious tubercle will be found in the angle between two of the rays, and a line drawn through this brings out the existence of bilateral symmetry, though this is somewhat obscure. It is far more obvious in some other members of the phylum, as we shall see elsewhere. The tubercle (madreporite) just mentioned is riddled with minute holes, through which sea-water enters a set of tubes (water-vascular system). Some of these project below as tube-feet, that are used for crawling. Another noticeable feature is the possession of a strong limy skeleton embedded in the skin.

V. FLAT WORMS (PLATYHELMIA)

These creatures owe their name to the circumstance that in average cases their bodies are greatly flattened from above downwards (fig. 243).

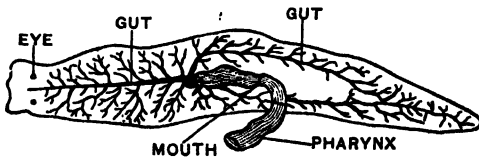


Fig. 243.—*Planaria lactea* (enlarged), with pharynx protruded to exterior

They include a vast assemblage of forms, of which many are parasitic (tapeworms and flukes), while others (planarian worms) live in salt or fresh water, or even in damp places on land. A typical aquatic planarian worm glides over stones or water

plants in search of prey, protruding a muscular tube (pharynx) from its mouth by which small creatures are seized (fig. 243). Great theoretical interest attaches to the non-parasitic members of this phylum, for they are the simplest of three-layered animals, and there are reasons for thinking that they have been derived from solitary ancestors resembling certain free-swimming zoophytes (Comb-jellies, a group distinct from Hydrozoa and Anthozoa), which have acquired a modified structure by taking to creeping.

VI. THREAD-WORMS (NEMATHELMIA)

These are cylindrical worms, of which the majority have taken to a parasitic mode of life. Their pedigree is very conjectural, and they are chiefly interesting on account of the diseases (trichinosis, &c.) for which they are responsible.

VII. ANNELIDS (ANNELIDA)

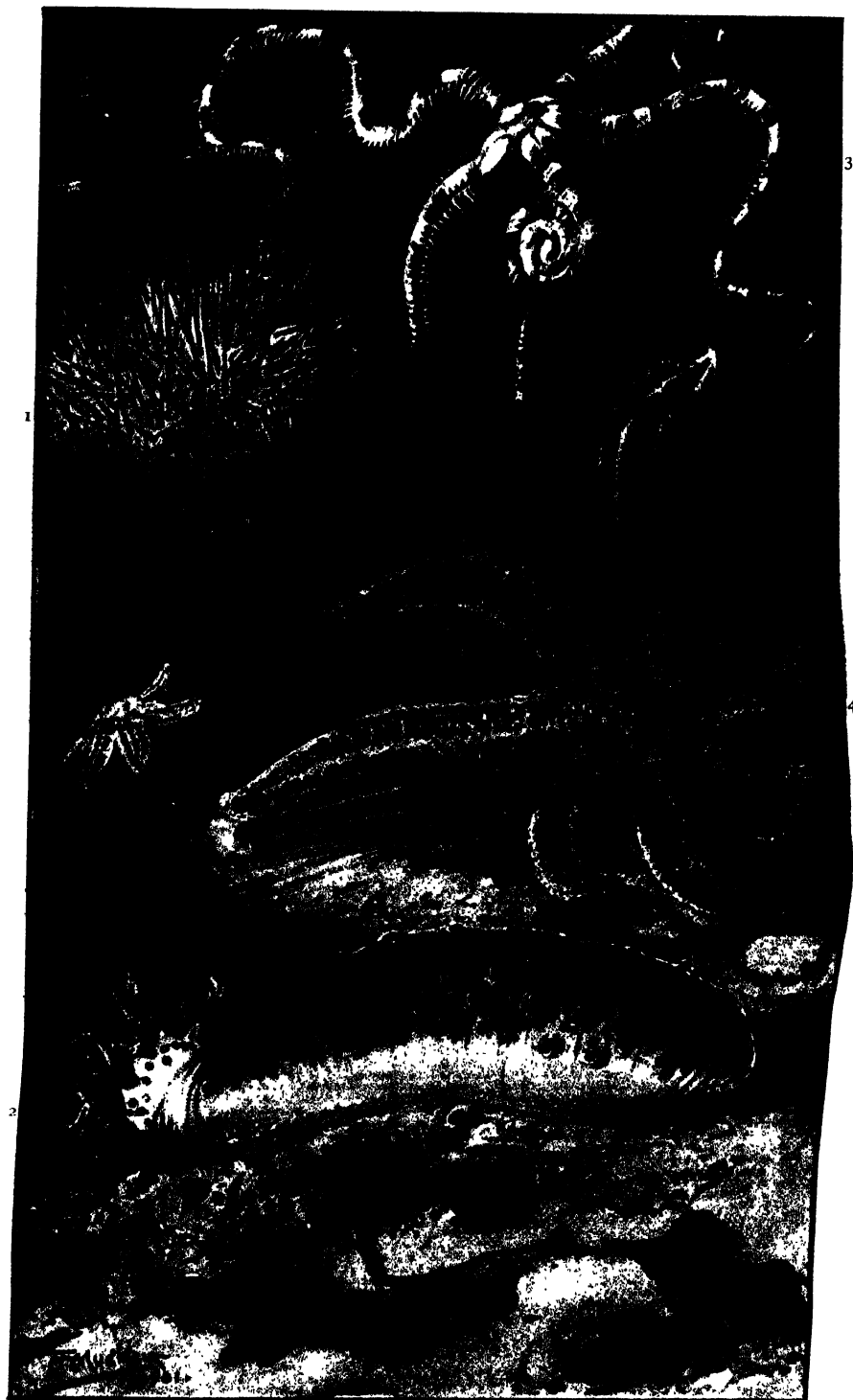
The three-layered animals so far described are *unsegmented*, i.e. their body is in one piece, and not divided into a succession of rings or segments. Such rings, however, are a distinctive character of the segmented worms which constitute this phylum, as familiarly exemplified by earthworms, and the innumerable marine worms that crawl on the shore between tide-marks. There are two chief subdivisions—(1) Bristle-worms and (2) Leeches.

ECHINODERMS

The animals here included constitute a well-marked group of marine animals, in which the body is typically star-shaped or spheroidal, or less commonly cylindrical. There is a more or less perfect calcareous skeleton developed in the skin, and part of it may consist of fixed or movable spines, hence the name of the group (Gk. *echinos*, a hedgehog; *derma*, skin: *i.e.* hedgehog-skinned). A peculiar system of tubes is present, containing sea-water and communicating with the exterior. In three of the constituent classes (star-fish, sea-urchins, and sea-cucumbers) part of this "water-vascular" system consists of sucker-like *tube-feet*, which are used for executing crawling movements.

Four common British forms are figured as types of the four classes now dominant, *i.e.* Star-fish (*Asteroidea*), Brittle Stars (*Ophiuroidea*), Sea-urchins (*Echinoidea*), and Sea-cucumbers (*Holothuroidea*).

1. Purple-tipped Sea-urchin (*Echinus miliaris*). Body covered by numerous spines attached by ball-and-socket joints to little knobs. ("Urchin" is an old name for the hedgehog.)
2. Black Sea-cucumber (*Holothuria nigra*). Leathery skin, in which scattered calcareous plates are embedded.
3. Brittle Star (*Ophiura*). Disc-like body with five flexible limb-like arms.
4. Common Star-fish (*Uraster rubens*). With five arms which are extensions of the central body. (The large specimen figured has more than the usual number of arms.)



ECHINODERMS

1. Sea-urchin.

2. Black Sea-cucumber.

3. Brittle Star.

4. Common Starfish.

1. BRISTLE-WORMS (CHÆTOPODA).—A good average example of this group is afforded by the Sea-centipede (*Nereis*) (fig. 244). The front part of the body is modified into a fairly obvious head, bearing feelers and provided with four simple eyes. A muscular pharynx, with a pair of formidable horny jaws, can be protruded from the ventral mouth for the capture of prey. The rest of the animal is divided into a large number of rings or segments, each provided with a blunt foot-stump (*parapod*) on either side, within which setæ or bristles are embedded. As suggested by their name (Gk. *para*, at the side; *pous*, *podos*, a foot), the parapods serve for creeping, and their bristles are able to grip a slippery surface.

An earthworm is constructed on somewhat similar lines, but is much modified by adaptation to burrowing. The head is very ill-defined, and

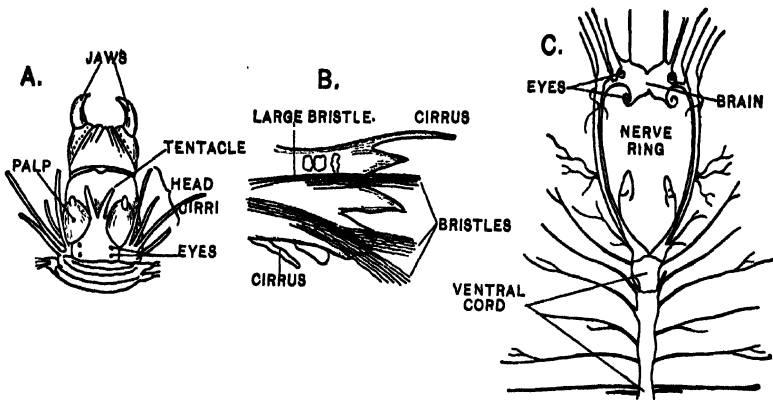


Fig. 244.—Structure of Sea-centipede (*Nereis*), enlarged to various scales

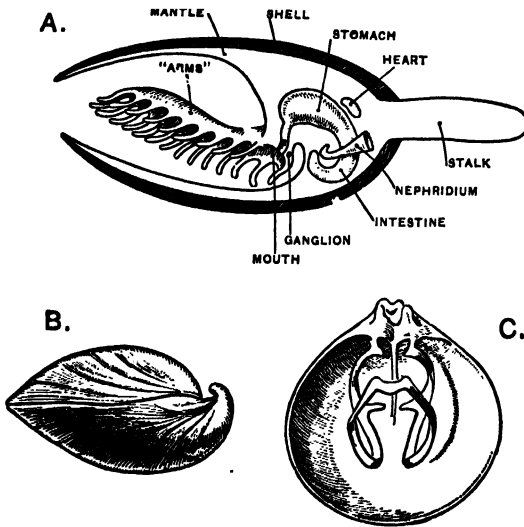
A, Head, with mouth-cavity everted and jaws protruding. B, A foot-stump (parapod). C, Front part of nervous system

possesses neither feelers nor eyes, which would only be a hindrance in underground life. The segments have lost their parapods, but a few bristles are retained, which aid progress through the burrows the creature makes.

The Sea-centipede is a good example of an "errant" (*i.e.* wandering) marine annelid that moves actively about, but some of the bristle-worms are tube-dwellers, living in tubes they construct or secrete, devoid of jaws, and depending for their food upon currents set up by the cilia covering the enormously enlarged branching tentacles developed upon their heads.

2. LEECHES (DISCOPHORA).—These are annelids which have nearly always lost the bristles as well as the parapods, and are provided with a sucker at each end of the body, enabling them to crawl along by a series of looping movements. The most familiar forms live on the blood of the higher animals, and possess saw-edged jaws for perforating the skin of their victims. They may therefore be described as external parasites (ectoparasites).

VIII. LAMP-SHELLS (BRACHIOPODS)

Fig. 245.—Lamp-shell (*Waldheimia*)

A, Diagram of structure; body cut through centre. B, Shell, seen from left side. C, Interior of dorsal valve, to show "carriage-spring" support for arms.

These curious creatures, of little importance at the present time, but once very dominant, are purely marine animals, remotely related to the Annelids so far as can be determined. They are enclosed in a calcareous shell, consisting of two pieces (valves), upper and lower respectively (fig. 245). A sort of stalk, usually serving for attachment to some firm object, protrudes from a hole in the lower valve, and (as in tube-worms) food is brought to the mouth by ciliary currents. In this case the current-producing organ (lophophore) consists of right and left branches ("arms") provided with numerous tentacles.

IX. MOSS-POLYPES (POLYZOA)

These unfamiliar nearly always colonial animals are mostly marine, though a few of them live in fresh water. They mostly possess an external, horny, or it may be calcareous skeleton, and superficially resemble hydroid Zoo-phytes, though in reality of much more complicated structure (fig. 246). They feed in the same way as the Lamp-shells, to which they are perhaps distantly related, and the current-producing organ is a plume of tentacles.



Fig. 246.—Polyzoa, enlarged

.Small colony of *Lophopus crystallinus*, showing some individuals fully extended, and others in different states of retraction.

X. JOINTED-LIMBED ANIMALS (ARTHROPODA)

The innumerable animals included in this phylum no doubt represent a specialized offshoot from primitive annelids, distinguished by fewer and more modified segments, and limbs divided into a number of joints. Omitting entirely extinct forms, it will be sufficient to enumerate the classes into which existing species are subdivided.

1. CRUSTACEA.—Nearly always aquatic. Water-fleas, barnacles, sandhoppers, woodlice (terrestrial), shrimps, prawns, lobsters, crayfish (fresh water), crabs (some terrestrial).

2. KING-CRABS (XIPHOSURA).—Represented by one widely distributed type (*Limulus*), with many resemblances to scorpions.

3. PRIMITIVE AIR-BREATHERS (PROTOTRACHEATA).—These are represented by a single type (*Peripatus*), widely distributed in tropical countries, and more closely related to Annelids than any existing Arthropod (fig. 247).

4. CENTIPEDES AND MILLIPEDES (MYRIAPODA).—Terrestrial animals presenting a considerable advance upon *Peripatus* in specialization.

5. INSECTS (INSECTA).—The most dominant class of existing terrestrial backboneless animals. Some of the primitive wingless forms closely resemble certain abbreviated centipedes, and this may be taken as an indication of pedigree.

6. SCORPIONS, SPIDERS, AND MITES (ARACHNIDA).—Nearly always terrestrial, but resembling King-crabs more closely than Insects.

XI. BACKBONED ANIMALS (VERTEBRATA OR CHORDATA)

These are segmented animals, living in all media, but their segmentation must not necessarily be regarded as indicating affinity with segmented INVERTEBRATES (a convenient term used when all other phyla are to be collectively indicated). The distinctive characters are possession of—(a) a backbone or equivalent structure; (b) openings (gill-slits) by which the front part of the digestive tube (pharynx) communicates with the exterior either for the whole of life or at any rate in the embryo, an arrangement primarily connected with breathing; (c) central nervous system (brain and spinal cord) hollow and dorsal. Omitting certain lowly classes, it will suffice to give the names of those into which existing forms are grouped; 1. FISHES (PISCES). 2. AMPHIBIA, *e.g.* newts, frogs, and toads. 3. REPTILES (REPTILIA), *e.g.* lizards, snakes, turtles and tortoises, crocodiles. 4. BIRDS (AVES). 5. MAMMALS (MAMMALIA), warm-blooded quadrupeds, and aquatic forms such as porpoises, whales, and sea-cows, in which the hind limbs have been lost.

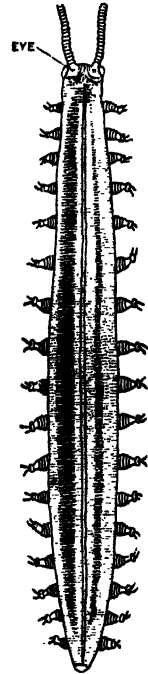


Fig. 247. — Cape Peripatus (*Peripatus Capensis*), enlarged

CHAPTER III

THE EVOLUTION OF ANIMALS IN GEOLOGICAL TIME—ARCHÆAN EPOCH—CAMBRIAN PERIOD

FOSSILS.—The kinds or species of animals now living have been compared to the leaves of a tree which a flood has almost entirely submerged, the parts under water corresponding to the innumerable host of species now mostly extinct. The branches of such a tree, to carry out the metaphor, may be taken to represent the groups of the animal kingdom. It was formerly the practice of zoologists in constructing their schemes of classification, expressing the affinities of groups, to consider only or mainly existing or recently extinct forms, and such schemes must necessarily be as faulty as conjectural drawings of a submerged tree founded on the evidence of the twigs and leaves appearing above the surface. Geologists, on the other hand, have until recent years been too much in the habit of relying on the study of extinct forms only, as represented almost entirely by bones, shells, &c., which as "fossils" are found embedded in the stratified rocks making up the geological record. It is now recognized that in solving problems relating to animals all possible data must be taken into consideration, and modern Zoology includes "palæozoology", which deals with the fossilized remains of formerly existing animals.

GEOLOGICAL RECORD.—The section on GEOLOGY has dealt with the evolution of existing areas of land and sea, the final term of a long series of mutations from times almost infinitely remote as judged by human chronological standards. The succession in time of stratified rocks from Archæan to Recent has there been set forth, and we now proceed to discuss the succession of animal associations (faunas) which have marked the geological ages through which our planet has passed. It is in the main, as might be expected on evolutionary principles, an advance from low to high, but many lowly types have been enabled to hold their own right through geological time, because they are adapted to conditions of life unaffected by the competition of higher forms.

IMPERFECTION OF THE GEOLOGICAL RECORD.—Only animals possessing hard parts, by way of an internal or external skeleton, are capable as a rule of leaving decipherable traces in the stratified rocks, though to this there are occasional exceptions, for impressions of even such perishable creatures as jelly-fishes are now and then found in strata of fine texture. Our knowledge, however, of the past history of most groups of Protozoa, of some Zoophytes, and all Flat-worms and Thread-worms is practically nil. Even if an animal possesses a hard skeleton, the chances of its preservation are but small, especially in the case of terrestrial forms. The vast herds of bison which once existed in North America have left but few marks of their existence, and the deposits now accumulating in the Gulf of Mexico probably enclose a very small number of bison bones. There is an even smaller chance that the remains of birds should be preserved.

The great mass of the deposits making up the geological record are of marine nature, and this is especially the case with those which date from the older periods of the earth's history. It naturally follows that while the story of life in the sea is comparatively full, that of life on land is more or less meagre. We must also remember that bones, shells, and other hard parts of calcareous nature are liable to be dissolved by percolating water should they chance to be enclosed in porous rocks, such as sandstones. It is, further, an undoubted fact that great thicknesses of fossiliferous strata have been worn away altogether or have been so altered that the remains of animals they may originally have contained are now unrecognizable. Taking all these facts into consideration the wonder is, not that the geological record should be imperfect, but that our knowledge of extinct animals is so full. The progress of investigation during late years has largely added to that knowledge, and the strata of America, India, and South Africa have proved veritable mines of information.

FIRST APPEARANCES OF ANIMAL GROUPS IN GEOLOGICAL TIME

Animal Groups.		Palæozoic.						Mesozoic.			Kainozoic.	
Invertebrates.	Protozoa ...	C	O	S	D	Cb	P	T	J	Cr	Tr	R
	Sponges ...	C	O	S	D	Cb	P	T	J	Cr	Tr	R
	Zoophytes ...	C	O	S	D	Cb	P	T	J	Cr	Tr	R
	Echinoderms ...	C	O	S	D	Cb	P	T	J	Cr	Tr	R
	Annelids ...	C	O	S	D	Cb	P	T	J	Cr	Tr	R
	Lamp-shells ...	C	O	S	D	Cb	P	T	J	Cr	Tr	R
	Moss-polypes ...	—	O	S	D	Cb	P	T	J	Cr	Tr	R
	Molluscs ...	C	O	S	D	Cb	P	T	J	Cr	Tr	R
	Arthropods ...	C	O	S	D	Cb	P	T	J	Cr	Tr	R
	Ostracoderms ...	—	—	S	D	—	—	—	—	—	—	—
Vertebrates.	Fishes ...	—	—	S	D	Cb	P	T	J	Cr	Tr	R
	Amphibia ...	—	—	—	—	Cb	P	T	J	Cr	Tr	R
	Reptilia ...	—	—	—	—	—	P	T	J	Cr	Tr	R
	Birds ...	—	—	—	—	—	—	—	J	Cr	Tr	R
	Mammals ...	—	—	—	—	—	—	?	J	Cr	Tr	R

C = Cambrian, O = Ordovician, S = Silurian, D = Devonian, Cb = Carboniferous, P = Permian, T = Trias, J = Jurassic, Cr = Cretaceous, Tr = Tertiary, R = Recent.

CHAPTERS OF THE GEOLOGICAL RECORD.—As elsewhere set forth in detail, it is convenient to divide the earth's history into four great epochs, ARCHÆAN, PALÆOZOIC, MESOZOIC, and KAINOZOIC, the last being by far the shortest, and the first in all probability by far the longest. Their actual time-value is very conjectural (see ASTRONOMY), but is undoubtedly far more considerable than once supposed. A formidable objection to the theory of evolution has been found in the time-limits imposed by astronomers and physicists. It is now admitted that their calculations were based on inadequate data, and, even supposing them to be correct, the objection would only be valid if evolution could

be assumed to be necessarily a very slow process during all the geological epochs.

ARCHÆAN EPOCH

This earliest part of the geological record has so far yielded no undoubted fossils, though it includes great thicknesses of unaltered strata (as well as extensive complexes of metamorphic rocks) the barren nature of which is rather extraordinary. For reasons which will be apparent later on, it must be admitted that animals of varied kind existed during Archæan times, and we may anticipate with some confidence that the remains of some of them will ultimately be discovered. So far only obscure markings have been described, interpreted by some authorities as the skeletons of certain Protozoa (Radiolaria), and the burrows or tracks of marine worms.

PALÆOZOIC EPOCH

This is divided into Cambrian, Ordovician, Silurian, Devonian, Carboniferous, and Permian periods, which will be briefly considered in succession.

CAMBRIAN PERIOD

The oldest rocks belonging to this early part of the geological record contain abundant fossils of very different kind, as will be realized by reference to fig. 248. They are all remains of Invertebrates, but it is clear that several groups of these had a long evolutionary history behind them. Hence the certain conclusion that there must have been an Archæan fauna, though at present we know nothing definite about it except by inference.

GREAT VARIETY OF CAMBRIAN TYPES (fig. 248).—A glance at the accompanying table will show that all but one (Moss-polypes) of the Invertebrate groups possessing hard parts capable of preservation in the fossil state were represented in Cambrian times, and there can be little doubt that other groups devoid of hard parts were also present, those including in all probability the lowly ancestors of the Vertebrates or Backboned Animals.

FIXED AND SLUGGISH ANIMALS.—In those remote days when the struggle for existence was less keen than in later times, it is noteworthy that many forms were able to make a living either if fixed or able to progress in a comparatively slow fashion by crawling or burrowing. In fixed animals of the kind the food consists of minute organisms and organic particles contained in the surrounding water, and food-bearing currents are commonly set up by the agency of microscopic threads of living matter (cilia) that alternately bend and straighten (fig. 249). Among animals which subsist or probably subsisted in this way may be mentioned many Protozoa; Sponges; the primitive fixed Echinoderms (Cystoids, Blastoids, and Crinoids); tube-dwelling Annelids; and Lamp-shells (Brachiopods), which have probably been derived from a primitive annelid stock.

COMPETITION FOR FOOD.—Even in Cambrian times, however, there must have been considerable competition for food, as evidenced by the

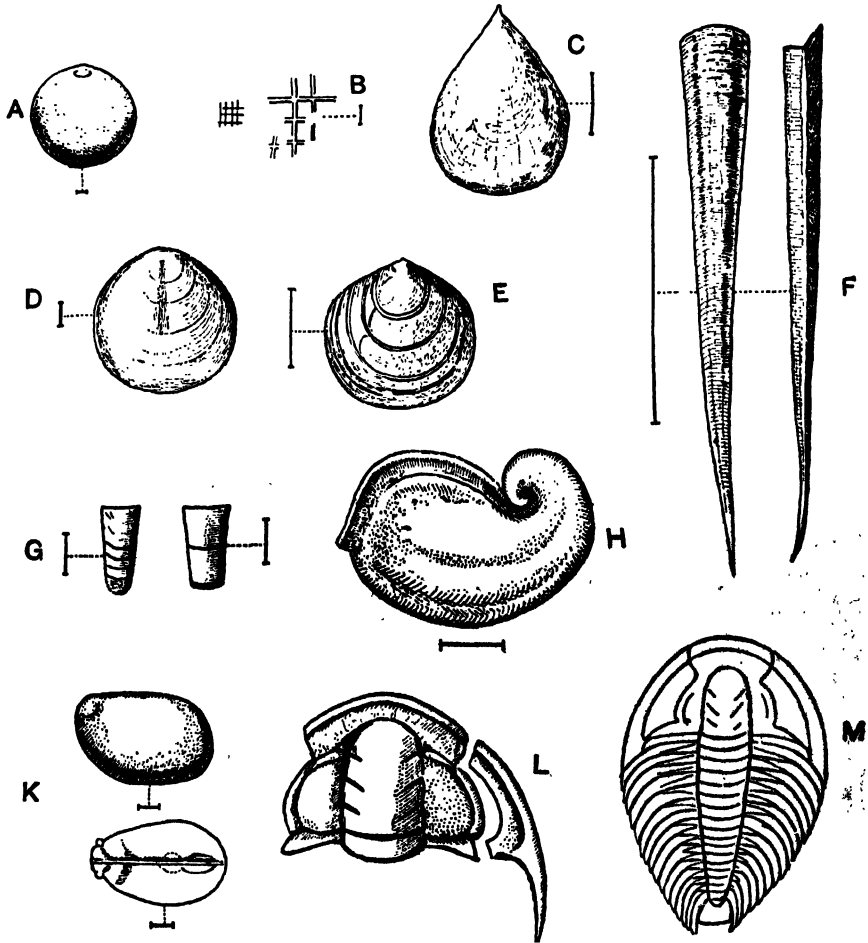


Fig. 248.—Earliest known Forms of Life (from American Cambrian)

A, Foraminifer. B, Sponge spicules. C, D, E, Lamp-shells. F, Doubtful organism. G, Cephalopod mollusc. H, Gastropod mollusc. I, Crustacean with bivalve shell (ostracod). L, M, Trilobites. Actual size indicated by lines.

presence of defensive arrangements against enemies. The Sponges, for instance, possessed as now a skeleton of sharp spicules of lime or flint, which probably warded off the attacks of the early Molluscs, and perhaps of some of the active Annelids. The most primitive Echinoderms, the fixed and commonly stalked Cystoids, possessed a strong defensive armour of calcareous plates, the sedentary Annelids lived in strong tubes, and the Lamp-shells had evolved a bivalve calcareous or horny shell.

III III

Fig. 249.—Ciliated Cells

PLANKTON.—The surface waters of the sea no doubt contained then as now a great wealth of available food, a leading factor in the evolution of

the floating and drifting forms of life which are collectively known as PLANKTON. To this belonged the Protozoa possessed of calcareous or siliceous shells, the Foraminifera and Radiolaria, which swarm in modern seas, on the floors of which extensive deposits known as ooze are made up from their hard parts. The jelly-fishes which no doubt then existed (mostly as stages in the life-histories of fixed Zoophytes) also belonged to the plankton, as did some of the early Molluscs (Cephalopods), of a kind now represented only by the Pearly Nautilus. Here, too, we must place

some at least of the curious extinct TRILOBITES, a purely Palæozoic group of Arthropods (fig. 250), which swam about on their backs by means of numerous pairs of forked limbs, as some of the simpler Crustacea did then and do still. It is also possible that some of the early sea snails (Gastropods) belonged to the plankton fauna (fig. 248, H), but this is uncertain.

CREEPERS AND BURROWERS.—Cambrian animals further included creeping and burrowing types. Among the former were in all probability some of the PROTOZOA, while the ancient STAR-FISHES of the period represented an Echinoderm type that has proved very successful, no doubt as a result of abandoning the fixed life, persistence in which has led to the extinction of more than one branch of the phylum. Many of the ANNELIDS were errant forms that crawled about in search of food, while some burrowed in marine deposits, swallowing sand and mud for the sake of the contained organic matter. Among burrowing forms we must also place the BIVALVE MOLLUSCS, though their mode of life seems to have been adopted as a defensive measure, since their food consists

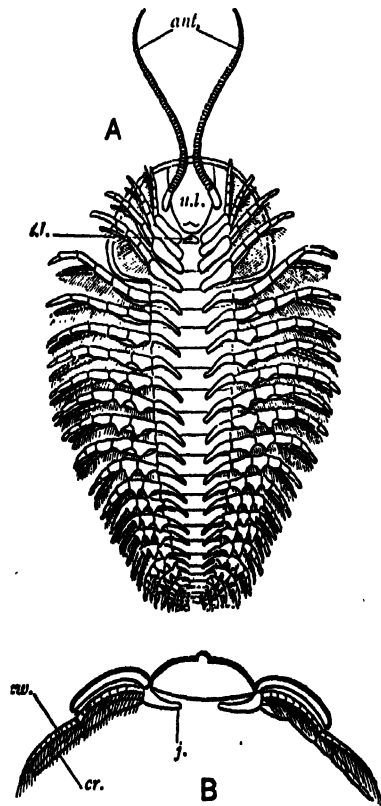


Fig. 250.—A, Under side of a Trilobite (*Triarthrus*) restored, showing the numerous jointed limbs. *ant.*, antennæ; *u.l.*, upper lip; *l.l.*, lower lip. B, Diagrammatic cross-section through same, showing limb-regions. *j.*, Projection serving as a jaw; *sw.* and *cr.*, swimming and creeping branches.

of minute organisms and organic particles contained in the seawater and carried to their mouths by ciliary currents. The enemies against which they sought protection were most likely star-fishes, judging from the habits of existing animals of that kind.

CHAPTER IV

THE EVOLUTION OF ANIMALS IN GEOLOGICAL TIME—ORDOVICIAN PERIOD

Another group of invertebrates is represented in the Ordovician period for the first time, *i.e.* that of the MOSS-POLYPS (Polyzoa), which are nearly all colonial and protected by a horny or calcareous external skeleton. They are perhaps distant relatives of the Lamp-shells, but superficially resemble some of the branching Zoophytes, though really much higher in the scale. Their food is brought to them by ciliary currents, as in so many other cases of fixed animals.

SEDENTARY TYPES.—Within the limits afforded by the area of surfaces available for attachment, and the amount of minute animals and

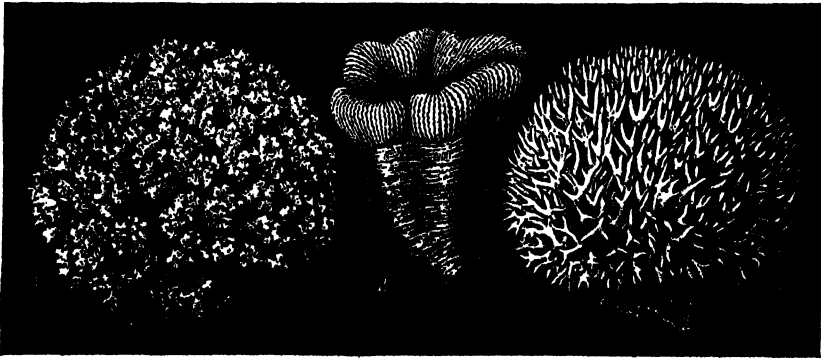


Fig. 251.—Skeletons of Corals, all reduced
2, Simple Coral. 1 and 3, Colonial Corals.

organic particles present in water, sedentary forms have occupied a prominent place in each of the successive faunas that have lived upon the earth. Besides the Moss-polypes just mentioned, these included in Ordovician times Lamp-shells in increasing number, Sponges, Tube-worms, very many Zoophytes (including corals), an abundance of Echinoderms, and a few Crustacea, regarding some of which forms a few words are necessary.

CORALS.—Among the Zoophytes known as SEA-FLOWERS (ANTHOZOA) the corals are abundantly preserved in the stratified rocks, owing to their possession of a calcareous skeleton. They are closely related to the familiar sea-anemones of the shore, which, however, possess no hard parts. A simple coral is practically an anemone of which the under part is calcified; and a compound or colonial coral (fig. 251) is an aggregate of polypes, each resembling in structure a small anemone. The bodies of these are united together by what may be termed a "common flesh" (*cænosarc*), with which is associated a "common skeleton" (*cænenchyma*) connecting the cups belonging to the individual members. Such a colony arises from a single original individual or founder polype by means of

budding or incomplete splitting (fission), and its form is determined by the particular way in which that process takes place.

Some of the compound corals are flat encrustations, others compact masses of various form, and others again branch in a plant-like way. The problem to be solved in any case is disposal of the individuals so as to give them a good chance of securing food. Here, as in other zoophytes, feeding is not entirely a matter of ciliary currents, for each polype is provided with numerous extensible tentacles armed with stinging cells, by which small crustacea and the like are paralysed or killed, being afterwards drawn into the mouth.

CORAL REEFS.—The most notable corals now living are reef-builders, and, being dependent upon clear warm water, are only found within a belt bounded by the parallels of 30 degrees north and south latitude. Coral reefs also existed in Ordovician times, but (as throughout the Palæozoic epoch) the most important corals helping in their formation belonged to an extinct group (*TETRA-CORALLA* or *RUGOSA*) which did not necessarily depend on the same conditions of climate as the reef-builders of to-day. But if they did, the occurrence of coral reefs during the Palæozoic epoch in our latitude could easily be explained, for we know that during the time covered by the geological record there have been extraordinary variations of climate within the same geographical area. (See *GEOLOGY*.)

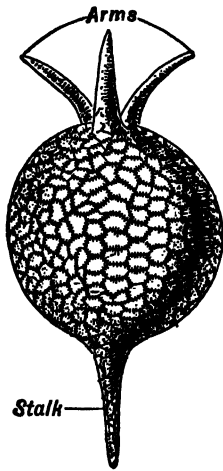


Fig. 252.—A Cystoid

The curiously extinct group of *STROMATOPOROIDS*, probably related to the Hydroid Zoophytes, also includes reef-building forms which abounded in the Ordovician and two following periods. They superficially resembled some of the more compact corals.

The **FIXED ECHINODERMS** of the Ordovician present many features of interest. Prominent among them are the **CYSTOIDS** (fig. 252), which are first found in the Cambrian, reach their maximum in the Ordovician and Silurian, greatly decrease in numbers during the Devonian, and become extinct in the Carboniferous. They are remarkable for their great diversity in form, some species being flattened discs, while others are ovoid or spheroidal. Certain species possess no stalk, while in others this organ of attachment is well developed. The mouth is on the upper side, and converging to it there are from three to five grooves, sometimes of branching nature, along which food particles were doubtless conducted to the mouth by ciliary action. In some cases at any rate the grooves were fringed with threadlike projections (armlets) which increased the catchment area for food, while in many instances these grooves pass on to simple arms (two to thirteen in number) serving the same purpose.

SKELETON OF CYSTOIDS.—The hard parts of an average Cystoid consist of numerous polygonal calcareous plates, not usually arranged in circlets or cycles. Many or some of them are perforated, though the meaning of this is uncertain. It may also be noticed that these animals

are either obviously bilaterally symmetrical, or else have become more or less radial. This and some other facts, *e.g.* the bilateral nature of the minute free-swimming larvæ, as which existing Echinoderms usually hatch out, lead us to suspect that Cystoids have been derived from ancestors which were not fixed but crawled or swam. The adoption of a fixed mode of life would gradually lead to masking of the original bilateral symmetry, and the acquisition of strong defensive armour is easily intelligible. All this, however, is at present conjectural.

EVOLUTION OF STALKS.—Cystoids are certainly to be regarded as the most primitive known Echinoderms, and probably represent or come near the stock from which the other groups have been directly or indirectly derived. Before proceeding to these other groups, a few words are necessary about the evolution of stalks. Animals which have abandoned the power of free locomotion and settled down upon the sea floor are liable to be gradually smothered by the accumulation of mud or ooze, a danger which is minimized or obviated by the development of a stalk. In some of the simpler Cystoids we find the lower part of the body is elongated and gradually tapers to a point. From this we pass by gradual stages to cases where the body, now termed the "cup" or "calyx", is borne on a flexible narrow stalk, also ending below in a point. We may suppose that in either case the pointed end of the body or stalk was embedded in mud or ooze. More rarely the stalk was firmly attached to some hard substance.

The **BLASTOIDS** (fig. 253) are a comparatively unimportant extinct group undoubtedly derived from the Cystoids, and consisting of a calyx made up of a comparatively small number of regularly arranged plates and a stalk of which the lower end is sometimes, if not always, branched in a rootlike way so as to give a better hold. Five petal-shaped food-conducting (ambulacral) areas lead to the mouth, and are fringed by long armlets serving the same purpose as those of Cystoids. Blastoids are first found in the Ordovician, increase in numbers until the early part of the Carboniferous, and then suddenly die out.

The **SEA-LILIES (CRINOIDS)** constitute another group of stalked Echinoderms (fig. 254), which, though represented in the Cambrian, do



Fig. 253.—A Blastoid

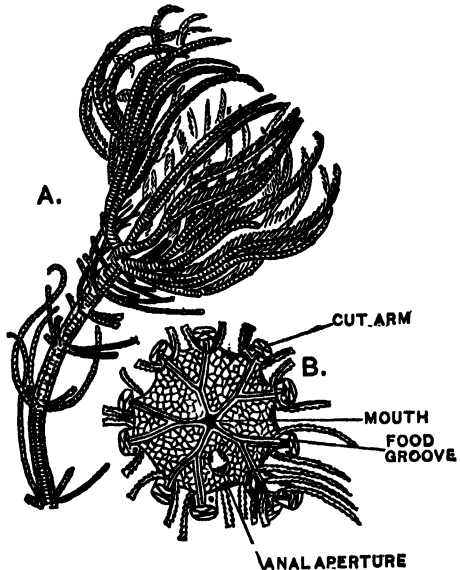


Fig. 254.—A Sea-lily (*Pentacrinus*)

A, Calyx and part of stalk (reduced). B, Upper side of calyx, with arms cut off.

not attain prominence till the Ordovician, reach their climax in the Silurian, and since then have gradually declined till at the present time they are only scantily represented in the fauna of the deep sea. Feather-stars, which also belong to the group, will be mentioned in the sequel. There can be no doubt that Sea-lilies are of Cystoid origin, and we are able to trace the stages by which they have arisen. These briefly consist in reduction of the number of plates in the calyx, and their regular arrangement, enormous development of the branching arms in relation to feeding and breathing, and perfecting of the stalk. The elaboration of the arms indicates increasing competition between various fixed forms for food obtainable by means of ciliary currents. Fixed animals which feed purely in this way find serious competitors in sedentary forms better equipped for the capture of small organisms, *e.g.* the Zoophytes, to which reference has already been made.

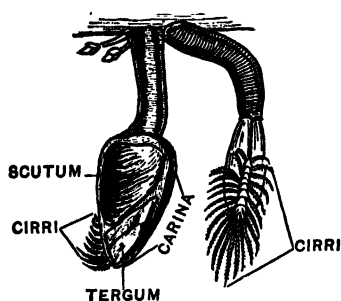


Fig. 255.—Ship-barnacles (*Lepas anatifera*), reduced

ADOPTION OF A FIXED LIFE.—In this connection we may note in passing that certain members of groups which mostly include active forms, have taken to a fixed life and intensified the struggle for existence which Cystoids, Blastoids, Crinoids, tube-dwelling Worms, and so forth, are obliged to keep up. Among CRUSTACEA, for example, the Barnacles, first represented in the Ordovician (or possibly even in the Cambrian), have adopted a fixed mode of life and acquired a protective shelly armour. Their legs have become slender tendril-like structures

fringed with hairs, and by alternate protrusion from and withdrawal into the shell act as a scoop net (fig. 255). Huxley expresses this in a graphic manner when he compares a barnacle to a man fixed by his head and getting a living by kicking food into his mouth.

ABANDONMENT OF A FIXED LIFE.—While Barnacles have given up a free life, some members of sedentary groups have adopted this, as is well exemplified among the Echinoderms—STAR-FISHES (ASTEROIDS), for example, of which the earliest known forms date from the Cambrian, and which have proved an eminently successful group up to the present day. They are very likely descended from Cystoids by loss of the stalk and other modifications, though such descent cannot be regarded as proved. The structure of a star-fish offers some very interesting points illustrating “change of function”, a most important factor in adaptation to new surroundings. The meaning of the expression briefly is, that organs evolved for one purpose may take on fresh duties.

CHANGE OF FUNCTION.—Like all Echinoderms, a star-fish possesses a “water-vascular system”, or set of tubes taking up seawater from the exterior. The early fixed Echinoderms undoubtedly possessed a water-vascular system most likely originally evolved in relation to breathing, *i.e.* the taking up of free oxygen and the elimination of the waste product carbon dioxide. In animals, *e.g.* sea-anemones, devoid of hard parts

this function can be discharged by the general surface of the body, which readily permits the diffusion of gases. But with the acquisition of an external skeleton such a method of respiration is no longer possible, and the evolution of special breathing organs becomes necessary. In the primitive fixed Echinoderms there was a continuous flow of pure oxygenated seawater through the tubes of the water-vascular system, the blind branches of which protruded through holes at the sides of the food grooves as delicate ciliated tentacles. From these the water could gradually diffuse to the exterior. These tentacles also assisted in the production of food-bringing ciliary currents, and served as organs of touch and possibly smell.

In Star-fishes and other free Echinoderms the tentacles mentioned have acquired the new function of locomotion, and the mouth is turned downwards instead of upwards. While the Star-fishes are first found in the Cambrian, the free-moving SEA-URCHINS (ECHINOIDS) are first represented in the Ordovician, and, like Palæozoic species generally, possess more plates than later types, and are of globular form. It has commonly been held that they are directly derived from Cystoids, but Sollas considers them to be an offshoot of the Star-fish class, basing his view on the fact that some ancient Star-fishes (*Palæodiscus*) possess an arrangement of jaws comparable to that found among the sea-urchins. If this be so it is difficult to understand the advantage of the globose form of the early members of the latter group. It certainly impedes active movement, and the subsequent stages of evolution have tended to replace it by a flattened shape.

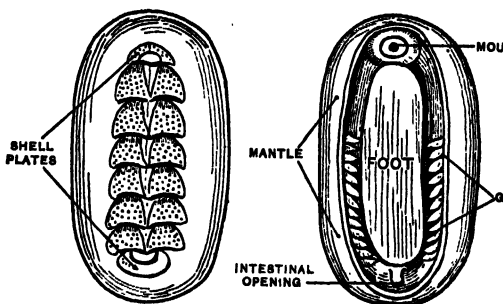


Fig. 256.—Mail-shell (*Chiton*), seen from above and below

Free Echinoderms were not the only creeping forms that lived in Ordovician seas.

CREEPING MOLLUSCS.—Passing by the numerous creeping Annelids, some of the Molluscs deserve a word of mention. Among the most primitive of these now existing are the flattened, symmetrical Coat-of-mail Shells (*Chitons*), living under stones and in crevices, and coming nearest the primitive type from which all Molluscs have descended (fig. 256). They are provided with a row of overlapping plates on the back, enabling them to roll up as a defensive measure. Their shells have been discovered in Ordovician strata. The SNAILS (GASTROPODS) are on the increase during this period, and have continued to become more prosperous till the present day. The early types appear to have been vegetarian in habit.

PLANKTON.—We next turn to the partly drifting, partly swimming plankton fauna of Ordovician times. At the present day there are large areas of the ocean surface which swarm with shell-bearing Protozoa, the Foraminifera and Radiolaria. The flinty skeletons of the latter cover

large tracts of the floor of the deep sea, not being so easily dissolved as the calcareous shells of the Foraminifera. In Ordovician (and Silurian) strata siliceous layers (cherts) are here and there found which contain the remains of Radiolaria, and therefore indicate deposition in very deep water. They are associated with black shales containing a large proportion of carbonaceous matter, some of which soil the fingers like coal, and enclosing innumerable remains of the extinct Palæozoic Zoophytes known as GRAPTOLITES, not distantly related to the Hydroid Zoophytes. It seems probable that large areas of the Ordovician (and Silurian) sea were covered by great masses of floating seaweed, as in the Sargasso Sea of the Atlantic at present, and to these the Graptolites appear to have been attached. The decaying seaweed most likely furnished the carbonaceous matter of the black shales.

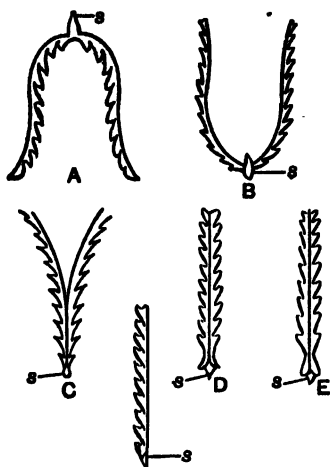


Fig. 257.—Evolution of Graptolites

s, Sicula, or cup of first polype, from which others bud. See text.

The evolution of Graptolites as set forth by Lapworth is a very interesting story. They are probably derived from some of the fixed, copiously-branched Zoophytes (*Cladophora*) which abound in the Upper Cambrian rocks, though this origin is not universally admitted.

Next came attachment to floating seaweeds with the branches directed downwards, these being gradually reduced in number; an illustration of the reduction of series with specialization of surviving members (fig. 257).

At last two-branched forms came into existence, both branches at first pointing downwards (*Dicellograptus*, A), and each row of cups for the polypes facing the other. An upward direction being more advantageous with

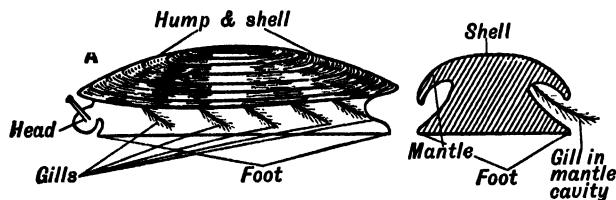


Fig. 258.—Archimollusc

A, Side view. B, Transverse section.

reference to food, the two branches began to turn upwards, ultimately leading to a type (*Didymograptus*, B), with the rows of cups necessarily turned away from each other. Greater stability was then secured

by partial fusion of the two branches, back to back (*Dicranograptus*, C) and ultimately complete fusion came about (*Diplograptus*, D, and *Climacograptus*). Competition between the two rows of individuals resulted in the diminution in size of one (*Dimorphograptus*, E), and ultimately to its entire suppression (*Monograptus*, F). The last kind of graptolite is only found in rocks of Silurian age.

EVOLUTION OF MOLLUSCS.—Some of the Ordovician Molluscs present points of considerable interest and importance. The group of HEAD-

FOOTED MOLLUSCS (CEPHALOPODS), at present represented by the Pearly Nautilus and Cuttle-fishes, then included a great variety of forms related to the former, but the latter had not yet been evolved. The remote ancestors from which all Molluscs, including Cephalopods, have been derived were lowly, flattened, creeping forms, defended by a simple shell, and of vegetarian habit (fig. 258). By means of a horny ribbon (*radula*), studded with minute teeth and stretched over a projection on the floor of the mouth, they were able to scrape off minute algæ encrusting rocks between tidemarks or in shallow water, and also to abrade the larger seaweeds.

EVOLUTION OF CEPHALOPODS.—The history of the Cephalopods, which, as the group is represented in the Lower Cambrian, must have begun in Archæan times, is essentially one of increasingly perfect adaptation to a rapacious free-swimming existence. It involved the drawing out of the upper part of the body into a kind of oblique hump, and a shortening of the foot (fig. 259). In other words, the old creeping axis of the body was replaced by a swimming axis having a different direction. According to the usually accepted view the front part of the foot grew round and fused with the head, being at the same time drawn out into lobes provided with sticky tentacles serving to capture prey. A powerful parrot-like beak was gradually evolved, the rasping organ became very powerful, and the eyes highly developed. The method of swimming that came into existence was a highly curious one, depending upon the utilization of the currents of water used for breathing, and leading to backward progression.

CEPHALOPOD SHELL.—One of the most remarkable characters of all Cephalopods, except Cuttle-fishes and their allies, is the possession of an external chambered shell, the last compartment of which is occupied in the Pearly Nautilus, and presumably in most extinct types, by the body of the animal. An imperfect shelly tube (traversed by a sort of cord united with the body) maintains connection between the successive chambers. The very earliest Cephalopods we may suppose to have possessed a simple thimble-shaped shell, and if we imagine this to increase in length by additions to its edge, successive chambers might arise by slipping of the animal towards the opening, with formation of shelly partitions one after the other. In some such way as this the familiar straight type (*Orthoceras*), represented from Lower Cambrian to Trias inclusive, must have come into existence (fig. 260). The chambered shell is generally believed to be a hydrostatic apparatus, helping to balance its owner in the water, and thus promoting drifting with currents or active swimming.

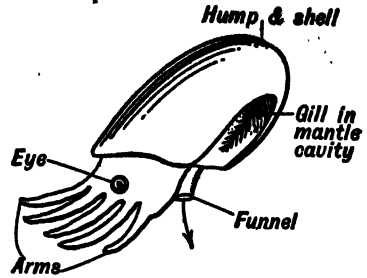


Fig. 259.—Cephalopod Evolution

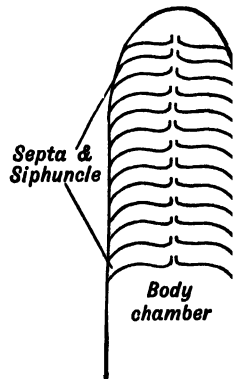


Fig. 260.—Orthoceras

Our only positive knowledge of the contents of the chambers of the shell is afforded by observations on the Pearly Nautilus, which is the only existing form possessing this arrangement. It has usually been assumed that the chambers contain gas, but Verrill states that, by means of certain pores and internal spaces which are present, "... seawater can readily pass into or out from the chambers of the shell, to equalize pressure at varying depths, as in most marine *Mollusca*. These chambers are unquestionably filled with fluid under normal conditions. But living as the animal does under pressure at considerable depths, the fluid in the chambers is saturated with the gases in solution. When the *Nautilus* is rapidly brought to the surface, some of the gas is liberated in consequence of diminished pressure, and must occupy part of the space within the chambers by forcing out some of the fluid. Hence the shell

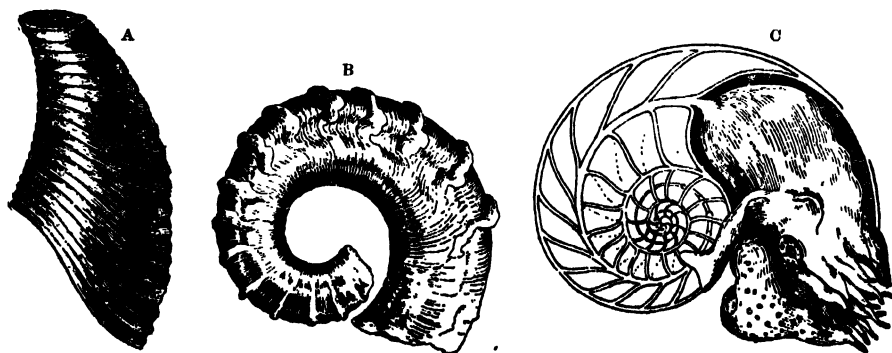


Fig. 261.—Evolution of Spiral Chambered Shell

will float until the free gases within the chambers are absorbed or otherwise eliminated. There is no evidence that free gases are ever naturally present in the ... chambers during life" (*Note* by Professor Verrill in the American translation of von Zittel's *Textbook of Palæontology*, Vol. I, p. 508).

The Pearly Nautilus, however, is perhaps somewhat exceptional in the fact that it has taken to a creeping mode of life, and it is not improbable that many of the ancient Cephalopods with chambered shells drifted and swam at or near the surface, feeding upon various plankton and other organisms. During the Ordovician and subsequent periods of the Palæozoic epoch we find a great variety in the form of chambered shells, many of them being comparatively short-lived, and apparently representing unsuccessful attempts to evolve an arrangement less likely to interfere with active movement than that presented by the long, straight type.

The most successful line of adaptation ultimately resulted in the evolution of a closely coiled spiral (fig. 261, C), and we can recognize a number of intermediate stages by which this has been derived from the primitive straight form (fig. 261, A, B). A survey of the facts leads to the conclusion that the struggle for existence in the sea between free forms was gradually becoming more intense, and animals that improved their swimming powers had a better chance of surviving; for, contrary to the old saying, the race is usually to the swift and the battle to the strong.

BIVALVES.—Among other Ordovician Molluscs we find rather more bivalves and sea-snails than in the Cambrian, but neither group is very strongly represented. As already explained (p. 112), BIVALVES (LAMELLIBRANCHS) represent an adaptation to the burrowing habit in the first instance, but even so early as Ordovician times some of them became fixed by means of a bundle of strong silky threads, the *byssus* (as well seen at the present time in the Sea-mussel). A more thorough-going method, evolved rather later, consisted in the attachment of one valve of the shell to some firm object, as exemplified by oysters.

An ordinary burrowing bivalve is bilaterally symmetrical, the right and left valves of the shell being mirror-images of each other, and there is a tendency for elongation from before backwards. But in the fixed forms, which lie down on the right or left valve during adult life, there is a gradual recurrence to the rounded shape, while the two valves are unlike each other. The lower one becomes a deeply concave receptacle for the body, while the other one becomes flattened and serves as a lid (fig. 262).

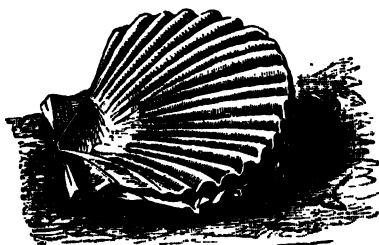


Fig. 262.—Pilgrim Scallop (*Pecten Jacobaeus*)

The muscular arrangements by which the shell closes also undergo modifications. In an ordinary bivalve there are two muscles (anterior and posterior adductors), which by their contraction pull the valves together, but the result of the sedentary life is to cause the anterior adductor to get smaller and smaller, while the posterior one increases in size. Ultimately the former disappears altogether, and the latter shifts to about the middle of the rounded shell. At the same time the organ of locomotion (foot) gradually dwindles and ultimately vanishes. A sea-mussel anchored by byssus, and only now and then casting off its moorings to seek more favourable quarters, has but a very small foot, while an oyster has none.

GASTROPODS.—It may be as well to say a little here about the derivation of SEA-SNAILS (GASTROPODS) from ancestors common to them and the Cephalopods. We may assume a stage in which a small oblique hump had been acquired, with a protective thimble-shaped shell (see fig. 263, A). At the back was a gill cavity, containing a couple of plume-like gills, and opening below just above the hind part of the foot. The formation of the hump was partly the result of the gathering up of the viscera so as to prevent them from interfering with the free action of the foot, thus enabling more active locomotion. The nature of the modifications by which Cephalopods were derived from a creature like that mentioned have already been described (p. 119), but here we are concerned with the evolution not of a swimming but of an actively creeping type.

This meant elongation of the foot, a change interfering with the passage of water into and out of the posterior gill cavity, the opening of which gradually shifted to the right, and ultimately moved upwards and

forwards till it faced directly to the front (fig. 263, B and C). The gill-cavity thus came to be placed over what we may call the neck-region, and brought the gills in front of the heart ("prosobranch" condition). These changes involved the twisting of the hump into a spiral covered by a shell of corresponding shape. Not only was unimpeded breathing thus

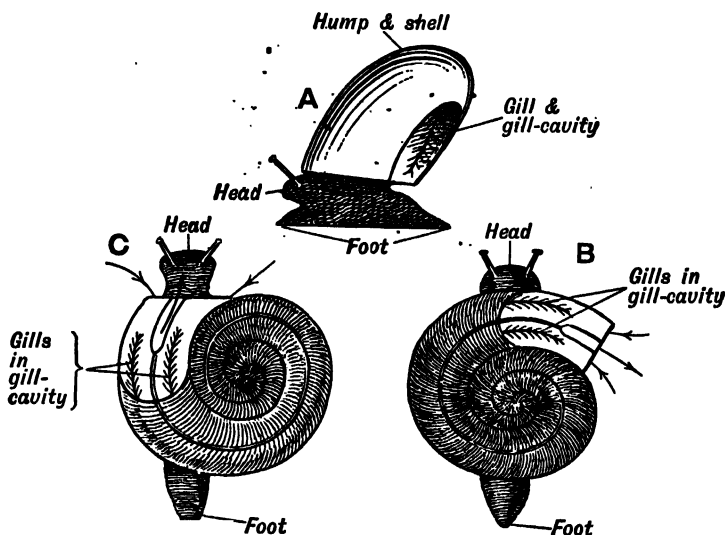


Fig. 263.—Gastropod Evolutions

provided for, but the twisted hump and shell were more convenient of carriage than if they had remained straight. Even after the unsymmetrical form had been attained, both gills were kept for a time, and they still persist in some of the more primitive existing types, e.g. *Pleurotomaria* (fig. 264) and its allies, which range from Cambrian to Recent. A further step in evolution consisted in the suppression of one of the gills, about which more will be said elsewhere. The earlier and more important part of the successive adaptations here briefly outlined must have taken place in Archæan times.

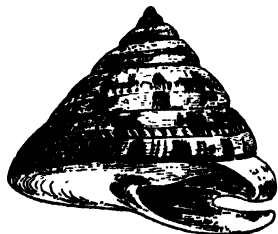


Fig. 264.—*Pleurotomaria*

voracious star-fishes. The fact that the under sides of their bodies were unarmoured, and the absence of powerful jaws, rendered them somewhat defenceless, but some of them acquired the power of rolling up, this increasing their chances of survival.

EURYPTERIDS.—During the Ordovician period, however, we find a better equipped and distinctly aggressive group of related animals rapidly evolving, which ultimately usurped the place in nature so far occupied

TRILOBITES.—Some of the Arthropods were of considerable importance in the Ordovician fauna. The Trilobites were still in their prime, and no doubt contributed to the diet of such free-swimming rapacious forms as Cephalopods, while the smaller ones were probably decimated by

by Trilobites. These were the EURYPTERIDS, possessing comparatively few but powerful limbs. King-crabs (Xiphosura) and scorpion-like forms (Arachnida) appear to have been derived from the same ancestral stock.

CRUSTACEA.—Lower Crustacea were abundant, especially the little MUSSEL-SHRIMPS (OSTRACODS), in which the body was enclosed in a bivalve shell (fig. 265). They lived together in large numbers, and either swam about or shuffled over the sea floor and over seaweeds in the search for food. The Higher Crustacea (Decapods) do not make their appearance

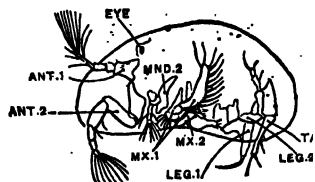


Fig. 265.—Mussel-Shrimp (*Cypris*)

ANT. 1, antennule; ANT. 2, antenna;
MND., mandible; MX. 1, first maxilla;
MX. 2, second maxilla.

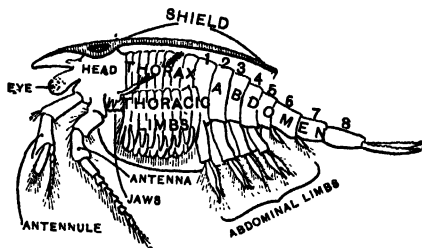


Fig. 266.—Mud-Shrimp (*Nebalia*), enlarged

Left half of shield cut away.

till much later in the geological record, but the curious MUD-SHRIMPS (LEPTOSTRACA), already represented in the Cambrian (by *Hymenocaris*), are somewhat more frequent in the Ordovician deposits (fig. 266). They are intermediate in character between lower and higher Crustacea, and the general tendency of evolution here and in other groups of Arthropods consists in reduction in number of segments with specialization of those remaining into well-marked regions (head, thorax, and abdomen) concerned with different functions, and bearing correspondingly modified appendages.

CHAPTER V

THE EVOLUTION OF ANIMALS IN GEOLOGICAL TIME—SILURIAN PERIOD

The marine fauna of the Silurian Period resembles in many ways that of the Ordovician, but the relative importance of different groups is not the same. In some of the calcareous strata, notably the Wenlock Limestone, reef-building CORALS abound, and numerous POLYZOA are associated with them.

GRAPTOLITES are rapidly on the wane, and but few of them survive into the next period (Devonian). *Monograptus* and its allies are particularly characteristic. Among ECHINODERMS the Sea-lilies are exceedingly abundant, so much so that the Silurian is sometimes termed the "Age of Crinoids". Towards the end of the period we find a new class represented, that of the BRITTLE-STARS (OPHIUroids), which hav

abandoned locomotion by means of tube-feet, and use their slender flexible "arms" as organs of progression (fig. 267).

LAMP-SHELLS are extremely abundant and characteristic, and attain their prime in this and the following period.

TRILOBITES, though represented by a number of highly organized forms, are distinctly on the down grade, while their rivals the EURYP-TERIDS are increasing in importance. In late Silurian times we find remains of a comparatively highly organized group of Crustacea (AMPHI-PODS), including Sand-hoppers, and distinguished by their laterally flattened bodies, correlated with springing powers, and unstalked (sessile) compound eyes. They are among the scavengers of the shore between tide-marks (fig. 268).

BIVALVE MOLLUSCS, though represented by primitive types, were actively on the increase, and relying as they did on food brought by

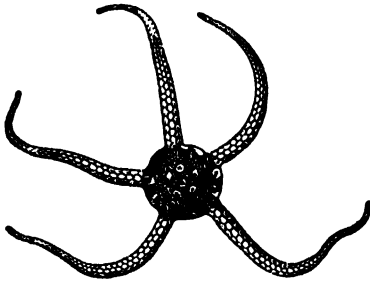


Fig. 267.—Brittle-star seen from above

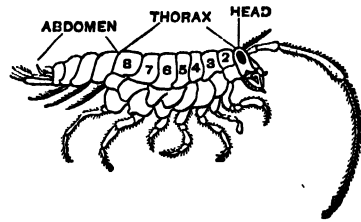


Fig. 268.—Sand-hopper (*Talitrus locusta*)

2-8, Last seven segments of thorax, the first is fused with the head

ciliary currents, began to compete seriously with the lamp-shells, over which the power most of them possessed of moving about gave a decided advantage. For this, among other reasons, we shall find that after the close of the Palæozoic epoch the lamp-shells steadily diminished in numbers and importance.

SEA-SNAILS, too, though not particularly prominent during Silurian times, were steadily on the increase, and as their evolution has progressed have added more and more to the competition for food among creeping forms. Until late Mesozoic times, however, they were mostly content with food of vegetable nature.

The nautiloid CEPHALOPODS with chambered shells of various shape attained their maximum in Silurian times, when some died out while others were initiated. Some of the straight types were very large, a length of about 8 ft. having been attained, it is said, in some cases.

FIRST VERTEBRATES.—The most interesting feature of the marine fauna of the Silurian is the appearance of backboned animals (fishes and lower types) at the end of the period. The ancestry of the group is entirely obscure, for the earliest forms, if we may judge from some existing primitive types, *e.g.* the Lancelet (*Amphioxus*), possessed no hard parts capable of preservation. Highly speculative views, based on the facts of anatomy and development, have been from time to time brought forward as to their nearest allies among the Invertebrates. A good

deal of stress has been laid upon the composition of the body from rings or segments, which are very obvious in the Lancelet, but far less distinct in higher types. For this, among other reasons, various investigators have sought to establish relationship with groups so diverse as Annelids, Crustacea, King-crabs, and Scorpions. The problem is so complex, and our knowledge is at present so incomplete, that details would be out of place here.

CHARACTERS OF VERTEBRATES.—Whatever may have been their origin, the Vertebrates are distinguished from other types by the possession of gill-slits, a hollow dorsal central nervous system, and a backbone or its equivalent (fig. 269). This equivalent, alone possessed in the Lancelet, but more or less supplemented, and it may be replaced, by gristle or bone in fishes and still higher forms, is technically known as the *notochord*. It is an elastic rod, formed as a ridge-like thickening of the roof of the digestive tube, running beneath the spinal cord and usually extending as far forwards as the middle of the brain. It serves to stiffen the body without rendering it unduly rigid, and was probably evolved as an adaptation to swimming.

The origin of GILL-SLITS can only be explained in conjectural fashion. It is at least absolutely certain that the earliest Vertebrates were jawless, and it seems pretty clear that their food was brought in currents set up by the agency of cilia lining the digestive tube, especially its front part. Such a method of feeding involves the inconvenience of swallowing an unnecessarily large quantity of water, and any arrangement helping to obviate this would prove an advantage.

It is supposed that in the first instance that part of the digestive tube (*i.e.* the *pharynx*) following the mouth-cavity became thrown into a series of pouches on either side, thus increasing the ciliated area producing currents and improving the food supply. Ultimately these pouches acquired openings to the exterior, through which the surplus water taken in at the mouth could pass away. Such openings would be gill-slits.

Account must here be taken of another important point. It is as essential for an animal to breathe as feed, and breathing (getting rid of waste carbon dioxide and taking in of free oxygen) can take place wherever the blood comes near the surface. We find, as a matter of fact, that in animals of various kind, where water is continually being taken into the digestive cavity, the lining of this plays a more or less important part in respiration. It is clear, therefore, that the acquisition of gill-slits would be an improvement in breathing as well as in feeding arrangements.

The notochord arises as a median dorsal fold of the digestive tube. Possibly its precursor was a groove by which food particles were directed backwards, and prevented from being washed away through the gill-slits.

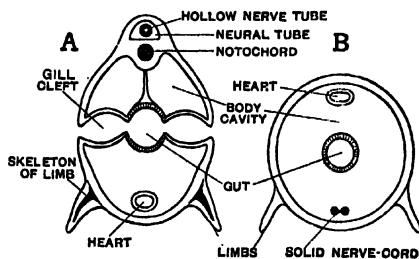


Fig. 269.—Diagrammatic Cross-sections through, A, a Vertebrate; B, a higher Invertebrate

The median position of the CENTRAL NERVOUS SYSTEM, concerned as it is with regulation and control, may be interpreted as acquired with reference to the efficient discharge of these functions. The most primitive nervous systems known are in the form of a sort of sheath surrounding the whole body in the deeper parts of the skin. With advancing specialization parts of this became concentrated into nerve-cords, some of which would naturally be longitudinal in a bilaterally symmetrical form. Given two or more of such cords there would be a struggle for supremacy

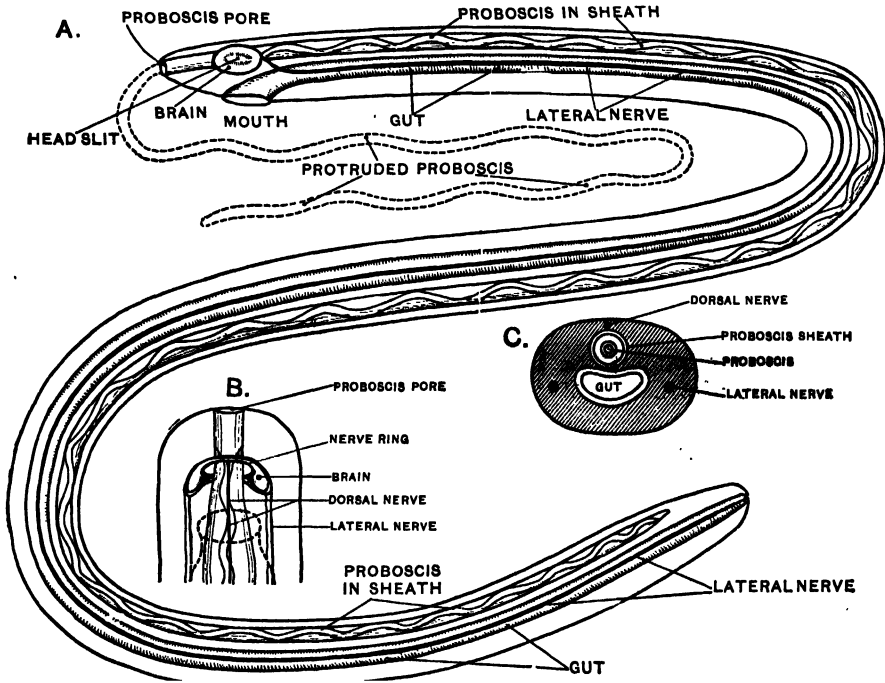


Fig. 270.—Structure of a Nemertine (diagrammatic)

A, Side view, internal organs seen by transparency. B, View from above of front end; position of mouth and beginning of gut indicated by the dotted line. C, Cross-section.

between them, and in this a median cord would have a great advantage, for it would help to control both sides of the body.

NEMERTINES.—There are at present in existence certain unsegmented marine worms, the NEMERTINES, which possess a stout cord on either side, and (in some cases) a thinner median dorsal one (fig. 270). Increase in size and complexity of the latter, with corresponding diminution of the others, would lead to the evolution of a central nervous system placed like that of Vertebrates. This and other reasons have led Hubrecht to advance the view that of all existing invertebrate forms Nemertine worms come nearest the ancestors of Vertebrates. The hollow nature of the brain and spinal cord is not difficult to explain. All nervous systems arise as thickenings in the outer layer (ectoderm) of the body-wall, and in Vertebrates a strip of this is folded in so as to form a tube lying

beneath the surface. Considering the delicate nature of such a system when highly specialized, the advantage of withdrawal from the surface, as a protective measure, is readily intelligible.

BONE-BED. OSTRACODERMS.—In a bone bed at the top of the Silurian we find the earliest known remains of aquatic Vertebrates, the lowest of these belonging to the groups of OSTRACODERMS, resembling Fishes in general form, but of distinctly lower type. They possessed neither paired fins nor lower jaw, the front part of the body was covered with shell-like armour-plating, and the hinder part with bony scales. There was an unsymmetrical tail fin and a dorsal fin in the back (fig. 271). The Ostracoderms lived on into the succeeding Devonian period, before the end of which they became extinct.

SHARKS.—The Silurian bone bed also contains scales and spines undoubtedly belonging to fishes of the SHARK ORDER (ELASMOBRANCHS). Fishes are Vertebrates of distinctly higher grade than Ostracoderms, possessing as they do a biting mouth with movable lower jaw and paired fins, *pectoral* in front and *pelvic* behind (fig. 272). Both improvements would appear to have come about by natural selection of the fittest under stress of competition with Cephalopod Molluscs, which so far were the dominant marine swimmers. But the exact manner of origin of lower jaw and paired fins is very difficult, for lack of material, to fully understand.

ORIGIN OF LOWER JAW.—As already stated, the most primitive Vertebrates undoubtedly fed on minute organisms and organic particles brought into the mouth by ciliary currents. Judging from fish-like animals of the LAMPREY CLASS (CYCLOSTOMES), the first improvement upon this was a bell-shaped suctional mouth with margin strengthened



Fig. 271. — An Ostracoderm (Cephalaspis), much reduced

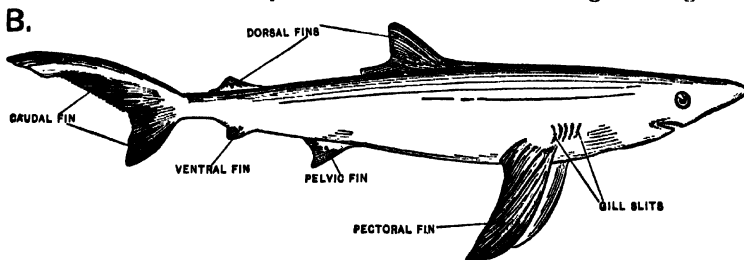


Fig. 272. — Blue Shark (*Carcharias glaucus*)

by gristly pieces, and a scraping arrangement for rasping away pieces of flesh from the prey. By development of a hinge joint between upper and lower moieties of its gristly skeleton a definite biting mouth, with upper and lower jaws, might conceivably come into existence.

It has, however, been suggested that the existing mouth of the lamprey has been formed by the fusion of a pair of gill arches. The position of the lower jaw corresponds to the skeletal position of the gill arches.

ORIGIN OF FINS.—The *unpaired* fins, situated in the

plane, are almost certainly the remains of a continuous fold, originally evolved to prevent the body from tilting over unduly to right or left. Similarly the *paired* fins may be regarded as the enlarged remains of continuous lateral folds, which also had reference to the balancing of the body in the water (fig. 273).

The suppression of parts of the original continuous fins was no doubt the result of more perfect adaptation to swimming and balancing. Progress through the water by lateral undulations of the body would probably be hindered by continuous lateral fins. The retention of anterior and posterior sections of these (as pectoral and pelvic fins) would suffice for balancing, and these remnants, by modifications in form and the acquisition of special powers of movement, would gradually become effective steering

organs. Similarly, the abolition of portions of the continuous median fin, while not interfering with balance, would diminish friction, while the enlargement of the terminal remnant, as a tail or caudal fin, would provide a powerful means of propulsion.

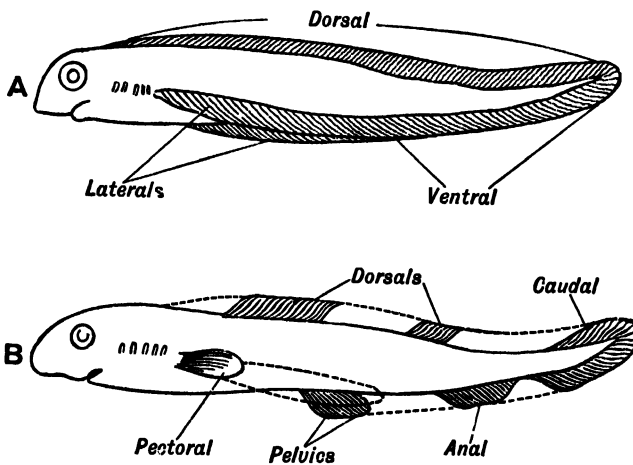


Fig. 273.—Origin of Fins

A, Fins continuous; B, Parts of continuous fins suppressed

CEPHALOPODS AND FISHES.—The two great groups of Cephalopod Molluscs and Fishes

have evolved side by side in their struggle for the mastery of the sea, and in either case the acquisition of increased speed has proved the touchstone of success in particular instances, as will abundantly appear in the sequel.

LAND FAUNA.—The fossils of the Silurian period give us, for the first time, a glimpse of the evolution of land animals, and we gather that such evolution must already have been progressing for an enormous length of time, though its earlier stages can only be material for speculation. In the rocks of New Brunswick, remains of terrestrial Molluscs and terrestrial Arthropods have been discovered.

LAND SNAILS.—We have elsewhere seen (p. 122) that in a typical sea-snail the breathing organs (*gills*) are contained in an anterior cavity (*gill chamber*) that opens to the front, and is roofed by a delicate fold of the body wall (*mantle*). The arrangement is one suited for extracting dissolved oxygen from water, with outward diffusion of the waste product carbonic acid gas (carbon dioxide).

The problem to be solved was the modification of this apparatus in such a way that it could absorb the oxygen of ordinary air. It may at

once be stated that all land snails do not belong to precisely the same sub-group. In other words, the problem has been solved independently more than once. But there can be no doubt that, as in other analogous cases, the area where one solution took place was the zone between tide-marks, where the environment regularly fluctuates between aquatic and terrestrial.

There are, as a matter of fact, a number of truly marine snails, *e.g.* some of the periwinkles (*Littorina*), which partly breathe *damp* air by means of the mantle forming the roof of the gill cavity. The last term in this line of evolution has been the total abolition of gills, and the conversion of the gill cavity into an air-breathing *lung* by modification of its roof. This is what we find in an ordinary garden snail to-day (fig. 274). It may readily be supposed that such an evolution as that indicated must have taken many ages to accomplish, and the fact that fully organized land snails existed in Silurian times points to a long antecedent period of gradual change.

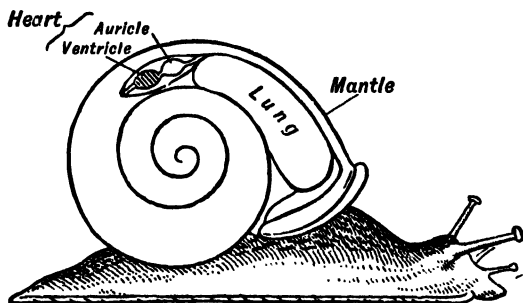


Fig. 274.—Garden Snail

LAND ARTHROPODS.—There can be no reasonable doubt that the jointed-limbed Invertebrates (Arthropods) have directly descended from creatures more or less resembling some of the existing segmented worms (Annelids), and the origin of aquatic Crustacea from such an ancestral stock is fairly clear. But when we come to terrestrial Arthropods *i.e.*, Peripatus (Prototracheates), Centipedes and Millipedes (Myriapods), Insects (Insecta), and Scorpions and Spiders (Arachnids), the evolutionary stages are difficult to realize, owing to dearth of material. Myriapods, Insects, and Arachnids are nevertheless represented in the Silurian land fauna.

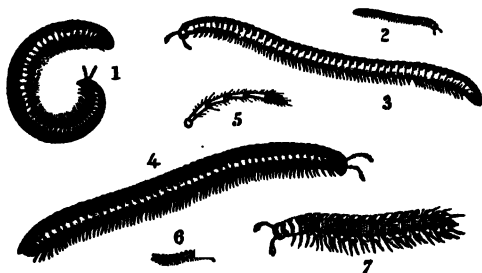


Fig. 275.—British Millipedes

1, London Snake-Millipede (*Julus Londinensis*); 2, 3, Spotted Snake-Millipede (*Julus guttatus*), natural size and enlarged; 4, 5, Earth Snake-Millipede (*Julus terrestris*) and antennae of same, both enlarged; 6, 7, Flattened Millipede (*Polydesmus complanatus*), natural size and enlarged.

MYRIAPODS.—It is very unfortunate that the archaic type *Peripatus* (see p. 107), undoubtedly a middle term between Annelids and terrestrial Arthropods, and its ancestors, have not, so far, been discovered in the fossil state. But the rather more specialized MYRIAPODS occur in Silurian rocks, and it will be worth our while to consider the chief ways in which these differ from marine Annelids (fig. 275).

The development of a comparatively thick horny external skeleton, preventing undue evaporation, and serving as a defence, is easy to understand, and so is the evolution of jointed legs from unjointed foot stumps, which are clearly ill-suited for effecting rapid progression on land.

But when we come to breathing organs the course of evolution is more difficult to comprehend. Marine Annelids breathe partly by means of their thin skin, partly by means of delicate gills, which are outgrowths of the body wall. Land Arthropods mostly breathe by thin-walled air-tubes (*tracheæ*) that ramify within the tissues of the body, or else by arrangements of comparable kind. The origin of these air-tubes is the point at issue.

Supposing Annelids living between tide-marks to become gradually adapted to life on land, the hardening of a part of the body wall would render it comparatively useless for respiratory purposes, while gills would gradually diminish in size, being unsuited to terrestrial life. A compensatory breathing surface might be formed by the passage of air into and out of the tubes or ducts placing glands of the skin in communication with the exterior. This is, at any rate, the only plausible hypothesis so far advanced to explain the origin of *tracheæ*. The openings of these would at first be scattered (as now in *Peripatus*), but with increasing specialization would be limited to the sides of the body, as in most recent land Arthropods.

Silurian Myriapods represent a comparatively advanced stage along evolutionary lines of the kind described, and the process most likely began in Archæan times.

INSECTS.—There is reason to think that Insects are descended from shortened Centipedes. In the latter, specialization has only taken place at the head-end, which is followed by a long trunk bearing numerous pairs of jointed legs. In Insects the body consists of three distinct regions—head, thorax, and abdomen—while the legs are reduced to six in number, all borne by the thorax. It is demonstrable, on mechanical principles, that six legs lend themselves admirably to climbing purposes, being advanced in alternate threes (two on one side, and one on the other), the three not for the moment in use serving as a supporting tripod.

WINGS OF INSECTS.—The most primitive existing insects are wingless, and these are represented among Silurian forms by Spring Tails (*THYSANURA*). The majority of insects, however, possess two pairs of thoracic wings, and the origin of these structures has next to be considered. It seems by no means improbable that they began as soft protrusions at the sides of the body suitable for breathing the damp air of the archaic swamps and forests. As the early insects would appear to have been climbers, these structures first became parachutes, and thereafter wings.

Silurian insects include winged types of the **COCKROACH ORDER** (*ORTHOPTERA*), some doubtful **SAND-FLIES** (*HYMENOPTERA*), and members of a large-winged generalized group (*PALÆODICTYOPTERA*), which has since become extinct. It may be mentioned here that a fossil insect (*Protocimex*) has been described from the Swedish Ordovician.

ARACHNIDS.—Scorpions (fig. 276), Spiders, and their near allies make up a characteristic land group, though this must have sprung from an aquatic stock. The typical breathing organs are *lung books*, pouches of the body wall, into which project a large number of delicate leaf-like folds. A lung book opens externally by a narrow slit, and its floor appears to be a modified limb.

SCORPIONS AND KING-CRABS.—A strong indication of the character of the aquatic Arachnid ancestors is afforded by the many points of

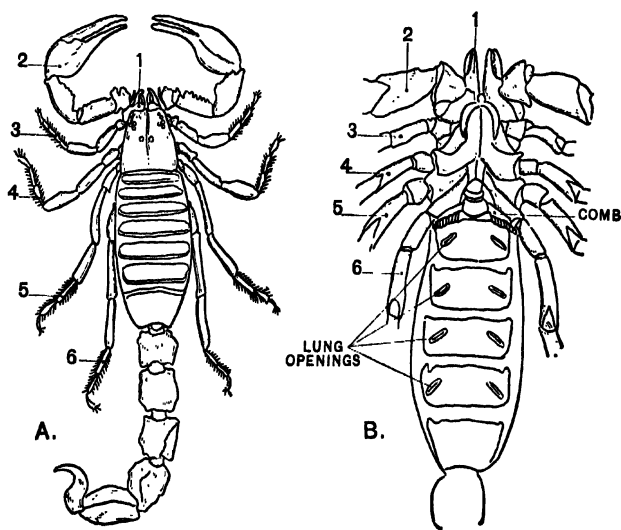


Fig. 276.—Scorpion, seen from above (A) and below (B)

1, Chelicerae; 2, pedipalps; 3-6, walking legs.

resemblance between Scorpions and King-crabs, and there are also points of affinity with the extinct Eurypterids and Trilobites. Scorpions are found in the Silurian strata, but doubt has been thrown upon their terrestrial character, the existence of lung books not having been demonstrated.

CHAPTER VI

THE EVOLUTION OF ANIMALS IN GEOLOGICAL TIME—DEVONIAN, CARBONIFEROUS, PERMO-CARBONIFEROUS, AND PERMIAN PERIODS

DEVONIAN PERIOD

The Devonian period is the first regarding which we have more than conjectural knowledge of the land and of freshwater areas (Old Red Sandstone), as well as of the sea (Devonian proper). There is obvious continuity

with the Silurian as regards classes, but different families and genera, some very distinctive, make their appearance.

MARINE FAUNA.—CORALS of various kind abounded, and many built up reefs. The remains of such animals are common in the limestones of South Devon and elsewhere. They are associated with the curious massive Hydrozoa known as STROMATOPORIDS (fig. 277), first found in Silurian rocks, and dying out during the Carboniferous period.

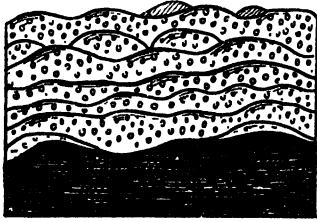


Fig. 277.—Stromatoporeid

GRAPTOLITES, on the decline in Silurian times, are exceedingly rare in Devonian rocks, and entirely absent from strata of later date.

Among ECHINODERMS we find both Cystoids and Blastoids on the decline, and both alike became extinct during Carboniferous times. Sea-lilies were also diminishing in number, but Sea-urchins, Star-fishes, and Brittle Stars were becoming dominant.

It may be said that LAMP-SHELLS (BRACHIOPODS) attained their maximum during the Silurian and Devonian periods, their subsequent decline being probably largely due to competition with bivalve Molluscs,

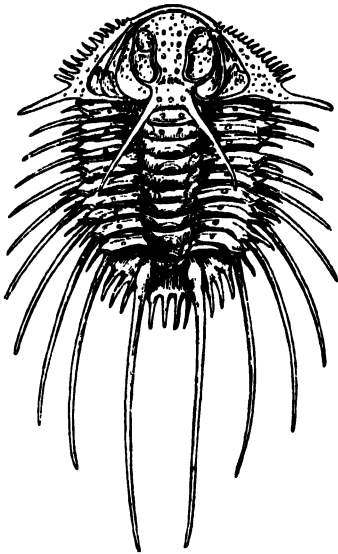


Fig. 278.—Spiny Trilobite (*Acidaspis*), (after Barrande)

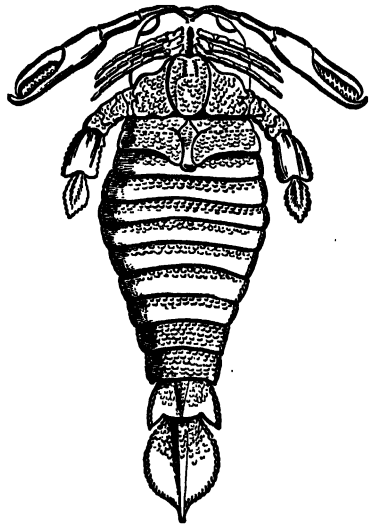


Fig. 279.—A Eurypterid (*Pterygotus*), much reduced

which, though feeding like them by means of ciliary currents, possessed the advantage of considerable powers of locomotion.

Coming to ARTHROPODS, a very interesting point is afforded by the great diminution in numbers of TRILOBITES, and the spiny character of many species (fig. 278). It is remarkable that the members of several declining groups have a tendency to become spinose. This is probably

in part a defensive measure, but may also be due to some innate law of development, the reasons for which are at present but dimly apprehended.

One reason for the decline of Trilobites is undoubtedly to be found in the rise of the better-organized EURYPTERIDS, which attained a remarkable development during Devonian times, some species being as much as 6 ft. in length (fig. 279). Trilobites, with their feeble limbs and comparatively slow movements, had but little chance of competing successfully with these larger and swifter rivals. Meanwhile the still more specialized CRUSTACEA were, so to speak, gradually making preparation to oust the Eurypterids from their dominant position.

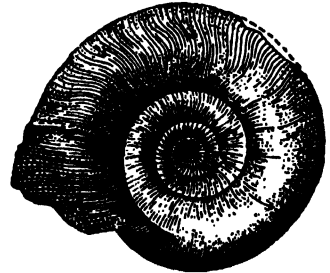


Fig. 280.—A Primitive Ammonite (*Prolocanites*), (after Sandberger)

The successful phylum of MOLLUSCA also made considerable progress in the Devonian period. Not only were the BIVALVES threatening the supremacy of the Lamp-shells, but the SEA-SNAILS (GASTROPODS) were perfecting their organization, and the nautiloid CEPHALOPODS were threatened by the first appearance of types with a flat spiral shell (*Ammonoids*) destined to be exceedingly abundant in the Mesozoic epoch (fig. 280). The latter type is distinguished by the folded edges of the partitions (*septa*) between the chambers of the shell,



Fig. 281.—An Ostracoderm (*Cephalaspis*)

though why this complication should be advantageous is very difficult to understand. Our complete ignorance of the soft parts precludes any definite solution of this problem, though a suggested explanation is given in a later chapter (see pp. 152-3).

Turning now to the VERTEBRATES, we find a large increase in the jawless OSTRACODERMS (fig. 281) and the jawed FISHES. Some of the



Fig. 282.—Coccosteus

former present a curious resemblance in form to Eurypterids, suggesting a similar mode of life leading to serious competition, which helped to render the latter extinct. Fishes would, of course, prove still more dangerous rivals to ambitious Arthropods. Superior mentally, as well as physically, their supremacy could not be denied. And from those remote

days to the present time fishes have perfected themselves in swimming and predaceous powers till now they are an exceedingly dominant group.

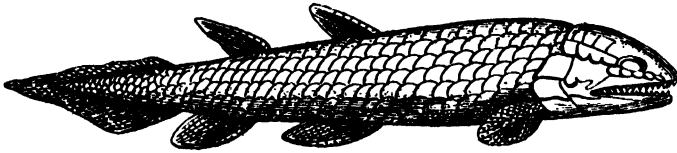


Fig. 283.—*Osteolepis* (after Pander)

Supremacy of the sea has in some sort been foreshadowed by piscine evolution, for the most effective ships of war, especially submarines, are modelled on the shape characteristic of fishes.

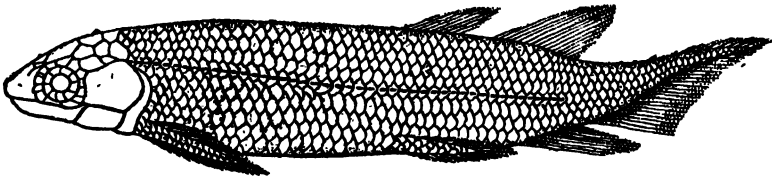


Fig. 284.—*Dipterus* (after Traquair)

SHARKS (ELASMOBRANCHS) are abundant and represented by species of very different kind. Curious armoured fishes (ARTHRODIRA) are particularly characteristic, and include many well-known types (COCCOSTEUS, &c., fig. 282). The FRINGE-FINNED FISHES (CROSSOPTERYGIANS), so named on account of the presence of a membranous margin to the paddle-like paired fins, and now existing as a scanty African remnant, are represented by several types (OSTEOLEPIS, &c., fig. 283).

We find also the first representatives of the existing LUNG-FISHES (DIPNOI), of which only a few species now live in Africa, South America, and Australia, as refugees into fresh water, which have converted the swim-bladder into a sort of lung. The Devonian types (*Dipterus*, *Phaneropleuron*, &c.) were purely marine (fig. 284).

All these Devonian fishes were comparatively clumsy, armour-plated forms with unequal (*heterocercal*) tails, and later on we shall find them more or less supplanted by swiftly swimming unarmoured types possessed of a strong internal skeleton and symmetrical tails.

FRESHWATER FAUNA.—The Old Red Sandstone rocks of Scotland, and perhaps also those of South Wales and the Welsh borders, were deposited in extensive freshwater lakes, and contain numerous fossils.

Fig. 285.—*Palæospondylus* (enlarged). (After Traquair.)

These include large numbers of Ostracoderms and Fishes of the kind already described for the marine fauna. It has indeed been suggested that such Vertebrates were evolved in fresh water, but this

appears to be highly improbable. Among the Old Red Sandstone types is a curious little elongated fish (*Palæospondylus*, fig. 285), sometimes held to be an ancient species of lamprey, though most likely it represents an extinct group of its own.

TERRESTRIAL FAUNA.—It need only be remarked that the Devonian land animals resembled those of Silurian times, but were represented by a greater variety of forms.

CARBONIFEROUS PERIOD

The Carboniferous strata were deposited under conditions of the most various kind, and their fossil contents give a fairly complete idea of the life of the period.

MARINE FAUNA.—Some of the FORAMINIFERA were of great importance as limestone builders, especially *Fusulina* (fig. 286), a comparatively large spindle-shaped type.

CORALS abound, and many of them were reef-builders, though quite unlike the forms now existing. Among the evidence proving the existence of marine ANNELIDS are the calcareous spiral investments of a tube-dweller (*Spirorbis*, fig. 287), so numerous as to build up a special limestone.

Fig. 286.—*Fusulina*
($\times 3$)



Fig. 287.—*Spirorbis*

BRACHIOPODS, though numerous, were on the wane, their place being usurped by BIVALVE MOLLUSCS, which showed a corresponding increase; SEA-SNAILS (GASTROPODS) were pretty common, and there were numerous members of the CUTTLE-FISH and NAUTILUS ORDER (CEPHALOPODS), some of these being decidedly more specialized than their Devonian predecessors. In this we see an adaptation to the increasing competition of the rapidly evolving fishes.

Two ancient stalked groups of Echinoderms, CYSTOIDS and BLASTOIDS, became extinct during Carboniferous times, their place being taken by more active types. SEA-LILIES (CRINOIDS) were still abundant, their remains playing an important part in building up some of the limestones, but the group was beginning to decline. Of other Echinoderm forms the SEA-URCHINS (ECHINOIDS) were remarkable for their spheroidal shape, and the possession of more numerous rows of plates than younger species.

TRILOBITES existed during Carboniferous times in greatly diminished numbers, and became entirely extinct in the succeeding period (Permian). The larger EURYPTERIDS, which helped to supplant them, occur for the last time in Carboniferous rocks; but stress of competition seems to have made them desert the sea, and to seek refuge in estuaries and fresh water.

Coming now to backboned animals, we find the OSTRACODERMS had died out, but FISHES of various kinds abounded, especially SHARKS (ELASMOBRANCHS), some with crushing teeth, and LUNG-FISHES (DIPNOI).

TERRESTRIAL FAUNA.—Various MILLIPEDES (MYRIAPODS) have been discovered in Carboniferous strata, and types apparently ancestral to the

closely related CENTIPEDES, distinguished by their poison-claws and carnivorous habit, have also been described.

INSECTS were comparatively numerous, and included PRIMITIVE WINGLESS TYPES (APTERA), COCKROACHES (ORTHOPTERA), MAY-FLIES (NEUROPTERA), and BUGS (HEMIPTERA). ARACHNIDS were represented not only by Scorpions and some other elongated forms, but also by the much more highly specialized Spiders. The evolution of the latter is

bound up with that of their prey, the insects. It may, indeed, be taken as a universal rule that great increase in numbers of any group means the increase of a possible food supply, and is accompanied by corresponding evolution of predaceous forms, some of which may even belong to the same group.

Several types of Carboniferous LAND SNAILS are known (fig. 288), as might be expected from the luxuriance of the land plants of the period.

The most interesting and important characteristic of the Carboniferous terrestrial fauna is the first appearance of land Vertebrates, in the form of AMPHIBIA, the remains of which have been discovered even in the lower strata belonging to this period.

Amphibia, chiefly represented in recent times by newts, salamanders, toads, and frogs, differ from fishes in several important respects. 1. When unpaired fins are present they are not supported by fin-rays. 2. What we may call "land limbs", transversely divided into regions, and split

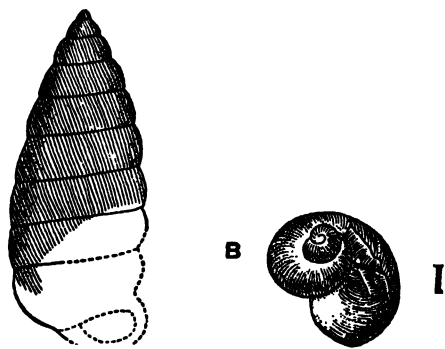


Fig. 288.—Carboniferous Land-snails

A, *Dendropupa*. B, *Archæozonites*. Lines show actual size (after Dawson).

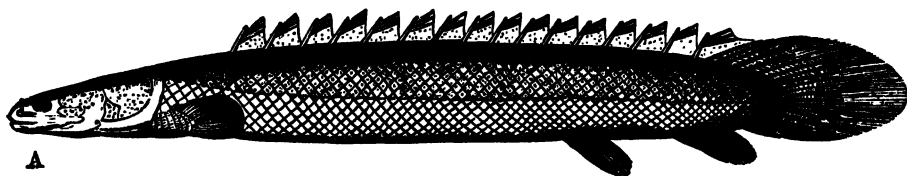


Fig. 289.—Bichir of the Nile (*Polypterus*)

into digits, replace the paddle-like paired fins of fishes. 3. Though gill-slits and gills are always present in the early larval stage of life (tadpole), they are later supplemented or entirely replaced by pouch-like lungs, which grow out from the under side of the gullet.

STEGOCEPHALA.—All the early Amphibia belong to an extinct order (Stegocephala) in which the head is covered by a protective armour of bony plates, while the rest of the body is more or less provided with hard scales or plates. They resemble in many ways the fringe-finned fishes (Crossopterygii) that abound in Devonian rocks, and have even

lingered on to the present day in some of the African rivers. One of these surviving forms, the Bichlr (*Polypterus*) of the Nile (fig. 289), possesses a double swim-bladder growing out from the under side of the gullet and partly used for breathing. This gives a useful clue to the origin of lungs, which develop as pouches in the same situation.

EVOLUTION OF LAND LIMBS.—It is most unfortunate that the extremities of the earliest Amphibia have not been preserved, and we have therefore no positive information as to the way in which land limbs have evolved from paired fins. Many speculations have been advanced regarding this, one of the most plausible being embodied in fig. 290.

Several sub-orders of Stegocephala existed during Carboniferous times. The oldest are the LABYRINTHODONTS, so named on account of the complicated way in which the enamel of the conical teeth was folded inwards.

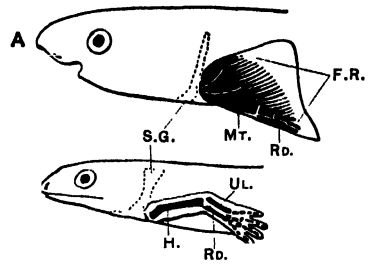


Fig. 290.—Comparison between Fore-limbs of Fish (A) and Land Vertebrate (B). (After Wiedersheim.)

S.G., Shoulder-girdle; MT., gristly plate at base of fin; F.R., fin-rays; H., humerus; RD., radius in B, large fin-ray in A; UL., ulna.

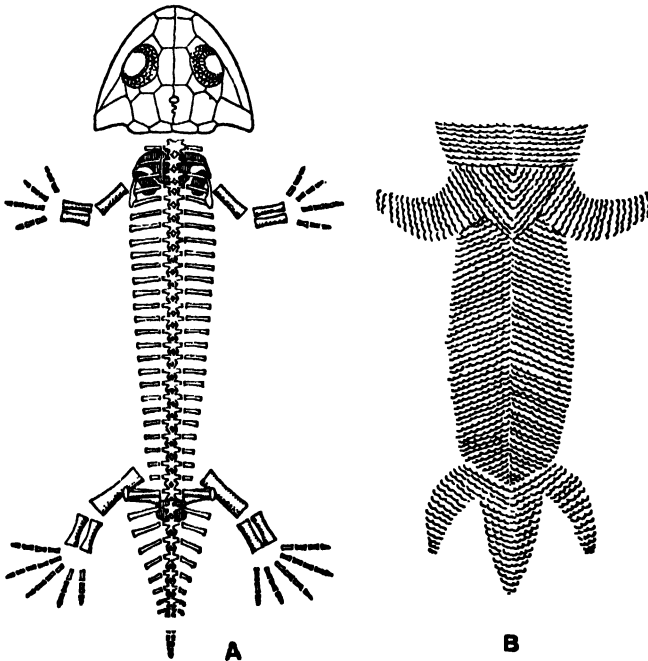


Fig. 291.—A Branchiosaur. A, Skeleton (from upper side) restored. B, Armour on under side (about natural size). (After Credner.)

In one of these from the Coal Measures (*Anthracosaurus*) the skull was over half a yard in length. Another group (BRANCHIOSAURIA) represented in the Upper Carboniferous included small salamander-like creatures

with long broad tails and traces of gill-arches and gill-slits (fig. 291). Limbless snake-shaped forms (CISTOPODA) also occur in the Upper Carboniferous, together with small lizard-shaped types (MICROSAURIA).

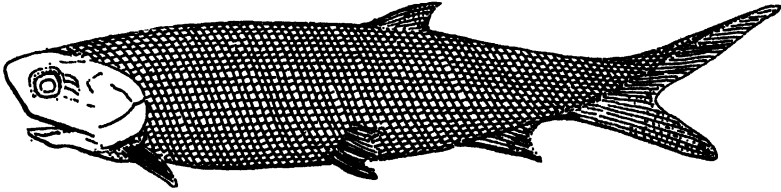


Fig. 292.—Permian Fish (*Palæoniscus*)

PERMO-CARBONIFEROUS PERIOD

Certain rocks occurring in Spitzbergen, the Ural Mountains, India, and Australia bridge the gap between the Carboniferous period and the succeeding Permian, and contain a marine fauna (largely consisting of Brachiopods) of intermediate nature.

PERMIAN PERIOD

This is the last stage of the Palæozoic epoch, and is represented in the British area by strata of somewhat anomalous nature, but more normal deposits are found elsewhere, and their fossil contents prove that the history of Palæozoic and Mesozoic life was continuous.

MARINE FAUNA.—MOSS-POLYPES (POLYZOA) were abundant, and BRACHIOPODS were common. The MOLLUSCA of all groups were clearly on the increase, and we notice among the Cephalopods an admixture of the older types with ammonite-like forms, destined to play an important part in the life of the Mesozoic epoch.

Among Permian FISHES we find the most specialized types (*Palæoniscus* and *Platysomus*) beginning to exhibit some of those features which have ultimately proved successful in the struggle for existence (fig. 292). The mouth, instead of being far back on the under side of the head, has shifted towards the front, a more convenient position for feeding; while the tail tends to become externally symmetrical, an adaptation to swimming straight ahead without steering.

TERRESTRIAL FAUNA.—The Permian AMPHIBIA belong to the extinct types already mentioned, one of the largest (*Archegosaurus*) being not less than $1\frac{1}{2}$ yd. in length.

Here, too, we meet for the first time with true REPTILES, undoubtedly descended from an Amphibian stock, but no longer partly dependent on aquatic life, for the gill-bearing tadpole stage has been eliminated from the life-history and they are preparing to assume the dominant position held by them during the Mesozoic epoch. Of these primitive Reptiles the members of one leading order (ANOMODONTIA) appear to have been intermediate in character between the extinct armoured Amphibia (*Stegcephala*) and the lowest egg-laying Mammals (Monotremata).

We also find representatives of the BEAKED REPTILES (RHYNCHOCERPHALA), lizard-shaped forms, of which one species (*Hatteria*) still exists on some small islands in the Bay of Plenty, New Zealand.

CHAPTER VII

THE EVOLUTION OF ANIMALS IN GEOLOGICAL TIME—MESOZOIC EPOCH—TRIASSIC PERIOD

MESOZOIC EPOCH

In this so-called "Age of Reptiles" we find a closer approximation to existing faunas than in Palæozoic times, as might be anticipated. Some of the Palæozoic Invertebrate types have entirely disappeared, *e.g.* Graptolites, Trilobites, and certain stalked Echinoderms (Cystoids and Blastoids), while the Corals, Sea-urchins, Sea-lilies, Brachiopods, and Molluscs are more complex in structure. The same is true for Fishes, Amphibia, and Reptiles, while Birds and Mammals made their first known appearance. Increasing competition rendered the struggle for existence keener, and in all directions we find greater specialization. The types less suited for competition fell out of the running, and others took their place.

TRIASSIC PERIOD

The British rocks of Triassic age (like those of the Permian) were deposited under abnormal conditions, but a review of the fossils from other areas, especially the Alps, shows that there was complete continuity between Palæozoic and Mesozoic faunas. Triassic strata contain a mixture of the older and newer types, and from here onwards we find forms which are intelligible by comparison with existing animals.

MARINE FAUNA.—The old four-rayed RUGOSE CORALS (TETRACORALLA) had now died out, and were replaced by six-rayed forms (HEXACORALLA) not unlike recent species. Many of them were reef-builders. Among HYDROZOA, the massive Stomatoporoids, characteristic of Silurian, Devonian, and Carboniferous, were replaced by branching, shrub-like HYDROID ZOOPHYTES.

BRACHIOPODS were distinctly on the wane, the most important genera being *Terebratula* and *Rhynchonella* (fig. 293), which commenced in the Palæozoic, attained a great development during the Mesozoic, and have lingered on, in much diminished numbers, to the present day.

Triassic MOLLUSCS present many features of special interest. The BIVALVES, which were gradually ousting the Brachiopods, included some

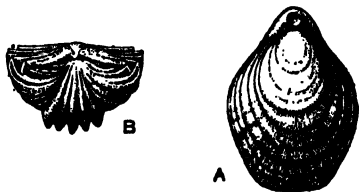


Fig. 293.—Typical Mesozoic Lamp-shells

A, *Terebratula*. B, *Rhynchonella*.

familiar types, such as Wing-shells (*Avicula*), Comb-shells (*Pecten*), and Cockles (*Cardium*). SEA-SNAILS (GASTROPODS) were beginning to become specialized, and mixed with the old vegetarian types we find a proportion of carnivorous forms, which become of increasing importance down to the present day. We may say, indeed, that though a certain position in the economy of nature always has existed, and always will exist, for sedentary or sluggish animals, increasing intensity in the struggle for existence sets a premium on rapid locomotion and the carnivorous or omnivorous habit.

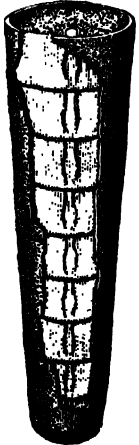


Fig. 294.—Chambered Part of Triassic Belemnite. Compare fig. 313, p. 153.

The last point is very clearly illustrated by the history of the class including CUTTLE-FISHES and the PEARLY NAUTILUS (CEPHALOPODS). During the Palæozoic epoch these were first represented by forms with a straight, chambered shell (*Orthoceras*), from which were evolved first curved and then spiral types, probably as an adaptation to more rapid swimming. During Triassic times we find the last survivors of Cephalopods with straight, external, chambered shells, and a great increase in those with a spiral, chambered shell, the partitions between the chambers being folded in a complicated manner. These "Ammonites" played a leading part in the marine Mesozoic fauna, but died out at its close.

CEPHALOPODS WITH INTERNAL SHELLS.—The reason for this is partly to be sought in the increasing specialization of fishes, partly in a new Cephalopod type which now appears upon the scene. The problem to be solved was the modification of a clumsy external shell that greatly hampered swimming. Here in the Trias we find the solution, which has proved eminently successful (fig. 294). The chambered

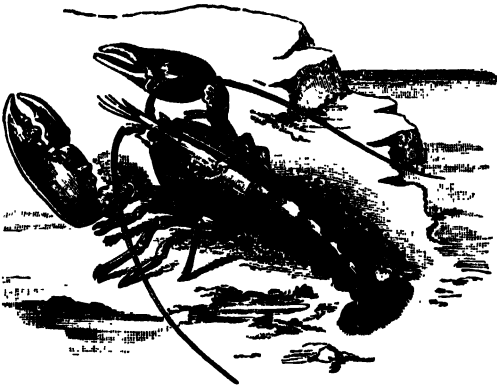


Fig. 295.—Lobster

shell straightened out, diminished in size, and by overgrowth of skin-folds became an "internal" shell, answering the purpose of a backbone in giving attachment to swimming muscles, and preventing "wobbling" by steadying the body. To it was added a hard cylindrical structure, the "guard", an especial characteristic of the "belemnite" type, which attained a great development during the

Mesozoic epoch. The guards of these extinct animals are found in vast numbers in rocks of this age, and are regarded by rustics as thunderbolts.

DECAPODS.—Among marine CRUSTACEA we find for the first time in the Trias members of the highest order (DECAPODS) of the class, to which modern lobsters, prawns, and shrimps belong, as well as the more

specialized crabs that made their appearance later and will be dealt with in due course. A crustacean of the lobster kind presents many advances

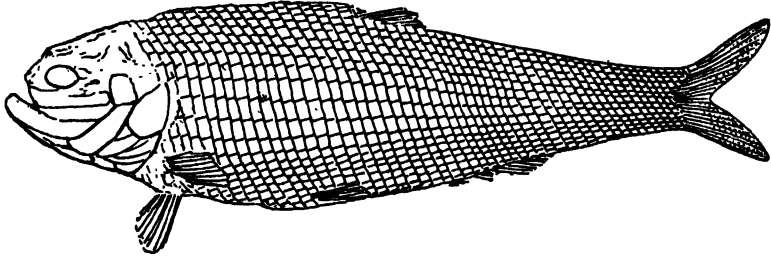


Fig. 296.—A Triassic Fish (*Photidophorus*) resembling a Primitive Herring

upon more lowly types of the class (fig. 295). The two front regions of the body (head and thorax) are relatively large, intimately fused together,

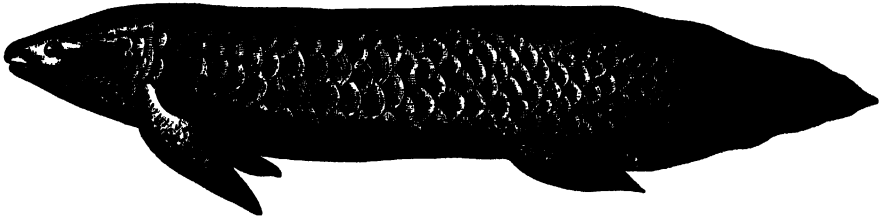


Fig. 297.—Australian Lung-fish (*Neoceratodus*)

and covered by a strong carapace, while the powerful tail ends in a large fin, which by flapping up and down effects very vigorous backward swimming. These arrangements are associated with well-developed muscles under the control of a highly complex nervous system.

In such a type, again, we find appendages of the most various kind, adapted for different purposes. The head bears stalked compound eyes, two pairs of feelers (ministering to touch, smell, and space perception), and three pairs of jaws. There are eight pairs of appendages in the thorax, *i.e.* three pairs of foot-jaws, a pair of pincers, and four pairs of walking legs. Taken together, the pincers and walking legs are *ten* in number, whence the name of "Decapoda" (Gr. *deka*, ten; *pous*, *podos*, a foot).

Triassic FISHES continued the line of evolution already described for the Permian. Armoured forms with an unsymmetrical tail, and the mouth on



Fig. 298.—Labyrinthodon

A, Tooth and footprints (reduced). u, Part of cross-section of tooth (enlarged). (After Owen.)

the under side of the head, were being supplanted by unarmoured types with a bony internal skeleton, symmetrical tails (enabling forward progression by unsteered swimming), and anterior mouth. We find, in fact, Triassic fishes not unlike herrings of a primitive kind (fig. 296).

During the Triassic period the LUNG-FISHES (DIPNOI), so far a marine group, appear to have deserted the sea, migrating up estuaries to become

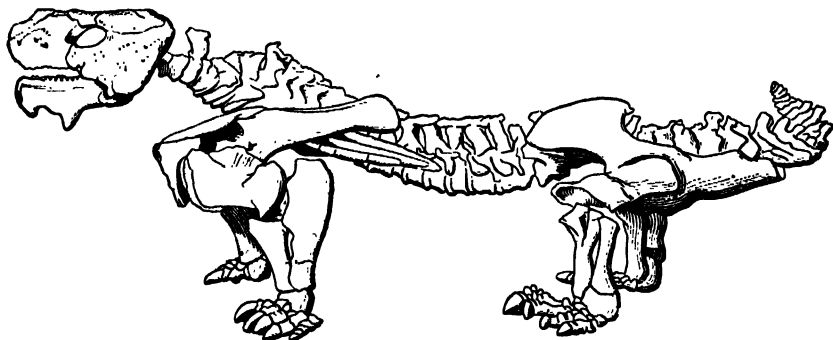


Fig. 299.—*Pariasaurus* (much reduced). (After Seeley.)

members of the freshwater fauna, exchanging the intense competition of marine life for less arduous conditions (fig. 297).

MARINE REPTILES.—A new factor in marine life, destined to be of considerable importance, made its appearance during Triassic times, for REPTILES began to occupy the place filled in modern times by sea Mammals, such as Cetacea. Some were long-necked types (SAUROPTERYGIA), not unlike lizards, and not much more than a yard long; others were short-necked creatures (ICHTHYOPTERYGIA), of similar dimensions.

TERRESTRIAL FAUNA.—Two fresh orders of INSECTS first appear in the Trias, *i.e.* BEETLES (COLEOPTERA), and MEMBRANE-WINGED INSECTS (HYMENOPTERA), represented by ants.

All the groups of armoured AMPHIBIA (STEGOCEPHALA) died out in the Palæozoic, with the single exception of the LABY-

RINTHODONTS (fig. 298), which are found for the last time in the Triassic rocks. One of these (*Mastodonsaurus*) was the largest of its kind, and must have resembled a gigantic salamander with a head over 4 ft. in length.

The first known fossil Reptiles, as we have seen, belonged to the Permian period, but during Triassic times the class underwent enormous expansion. The ancestral stock would appear to have resembled the extinct Amphibia just mentioned.

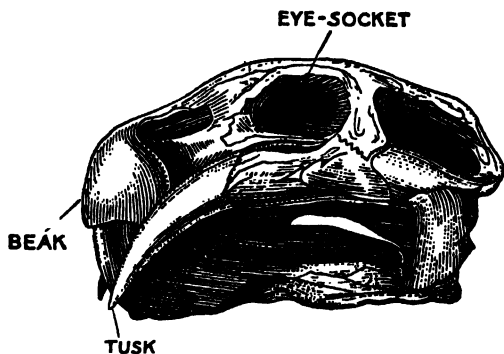


Fig. 300.—*Dacynodon* (after Owen)



Fig. 301.—The New Zealand Tuatara (*Hatteria punctata*), the only surviving Beaked Reptile

The DIVERSE-TOOTHED REPTILES (ANOMODONTS), confined so far as known to the Permian and Triassic periods, are particularly interesting because they appear to have been intermediate in character between the Labyrinthodonts and the lowest Mammals (Monotremes). They are of most diverse kind. One (*Pariasaurus*) is not unlike a clumsy caricature of a dog about 9 ft. long (fig. 299). Others (THERIODONTS) resembled Mammals in possessing teeth of markedly different kinds, and others again (DICYN-

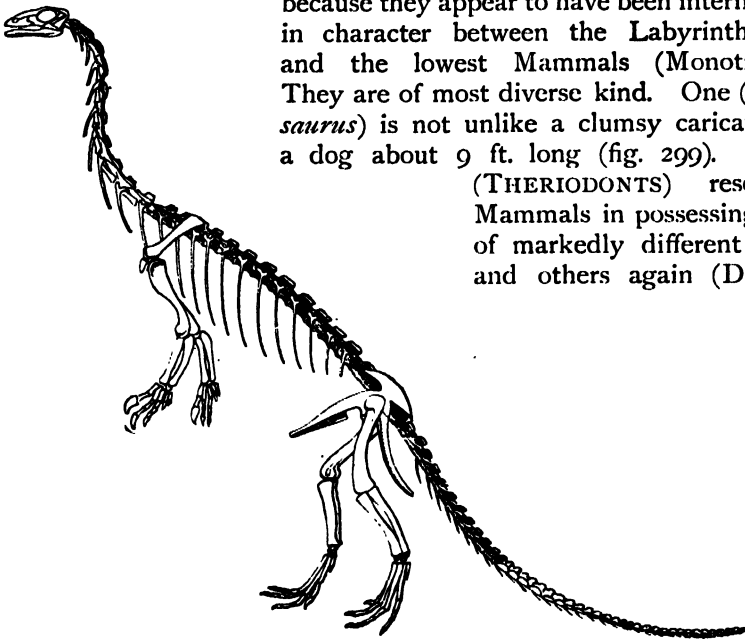


Fig. 302.—A Triassic Dinosaur (*Anchisaurus*) ($\times \frac{1}{8}$). (After Marsh.)

DONTS) either possessed no teeth at all or a pair of tusks in the upper jaw (fig. 300).

TURTLES (CHELONIA), distinguished by their extraordinary carapaces,

were first represented in this period. We also find members of the Beaked Reptile order (RHYNCHOCEPHALA), which made its first known appearance in the Permian (cp. fig. 301).

The Triassic rocks contain the remains of the first-discovered species of an exceedingly diversified order of land reptiles (DINOSAURIA) entirely limited to the Mesozoic epoch. The Triassic types were the carnivorous Theropods, which walked about on their hind legs and possessed long tails that helped to support their bodies (fig. 302).

Some Triassic Reptiles (*Belodon*, *Stagonolepis*) were very possibly ancestral to recent Crocodiles, creatures in which the internal apertures of the nose (internal nares) are placed very far back, and communicate with the top of the windpipe in such a way that the mouth can be kept open under water without fear of suffocation. In the Triassic types these apertures were fairly far forwards (fig. 303). In fact, if we trace the history of the order from its first appearance to recent times we shall find increasing

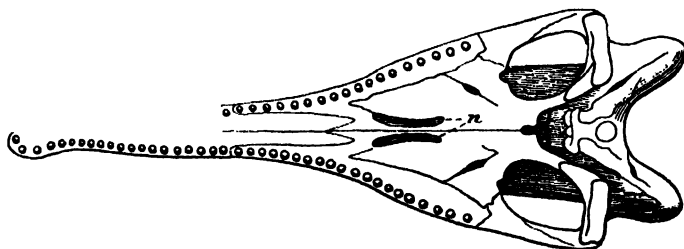


Fig. 303.—Under Side of Skull of Triassic Crocodile (*Belodon*). *n*, internal nares ($\times \frac{1}{2}$) (After von Meyer.)

adaptation to carnivorous life in rivers and estuaries. The prey not only consists of fishes and other aquatic vertebrates, but also of terrestrial vertebrates snapped up from the bank. Modern crocodiles often make comparatively large mammals their victims, holding them under water until drowned. The peculiar breathing arrangements are here particularly serviceable.

RISE OF MAMMALS.—Some fragmentary fossils from the youngest part of the Trias are probably referable to the Mammalia, a class of admittedly reptilian descent. Mammals are the dominant land vertebrates of the Kainozoic epoch, having deposed Reptiles from the leading position they occupied during Mesozoic times. As their most important distinctive characters are to be found in the structure of the soft parts, which are incapable of preservation in the fossil state, the early stages of their evolution must remain conjectural. As in many other cases we are obliged to depend on a study of the hard parts, which have evolved *pari passu* with the soft structures, and enable us to make more or less plausible guesses as to the nature of the latter.

CHARACTERS OF MAMMALS.—The most essential characters of mammals are to be found in (1) the skin, (2) the circulatory organs, and (3) the brain.

1. Mammals alone among backboned forms possess a covering of hair, as contrasted with the scales of reptiles and the feathers of birds. It is

generally conceded that hairs must have been evolved from scales, but the geological record does not furnish the material necessary for reconstructing the stages in this evolution. There can be little doubt, however, that a hairy covering gradually came into existence as a means of preventing the undue escape of heat from the body.

Another even more typical feature of the integument of mammals is to be found in the conversion of certain skin-glands into organs for the secretion of milk destined to nourish the young, an evolutionary factor of prime importance. Other things being equal, specialized arrangements for the care of young favour the survival of the species exhibiting them, and by reaction on the mental faculties help to promote the evolution of a large and complex brain.

2. The circulatory organs of mammals exhibit a complete solution of the problem of converting an arrangement suitable for a fish into one

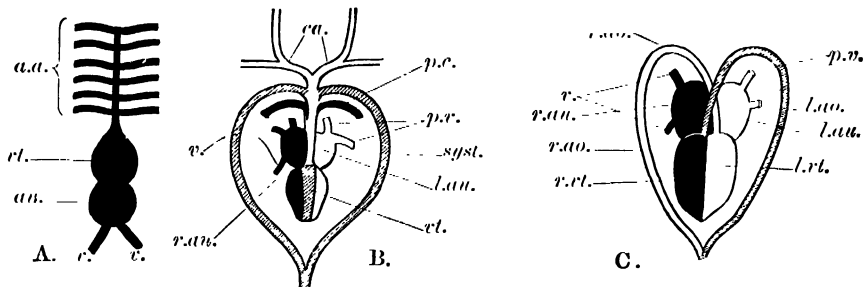


Fig. 304.—Heart and Great Blood-vessels (diagrammatic, of A, Fish; B, Frog; and C, Crocodile)

Black indicates impure blood, white, pure blood; and shading, mixed blood. *a.a.*, aortic arches; *au.*, auricle; *l.au.* and *r.au.*, left and right auricle; *l.a.u.* and *r.a.u.*, left and right aortic arches; *ca.*, carotid arches; *p.c.*, pulmonary arches; *p.v.*, pulmonary veins; *syst.*, systemic arches; *v.*, veins; *v.c.*, ventricle; *l.v.* and *r.v.*, left and right ventricles.

adapted to the needs of a land vertebrate breathing ordinary air. Three stages in the series are presented by a fish, a frog, and a crocodile (fig. 304). In a fish (the gills of which breathe the air dissolved in water) the heart essentially consists of two chambers, an *auricle*, which receives impure blood, and a *ventricle*, that pumps this to the gills for oxygenation.

The circulatory organs of a tadpole are similar to those of a fish. But the transformation of a tadpole into a frog involves the development of lungs for breathing ordinary air, and the blood thus oxygenated is returned directly to the heart. It would not do for this pure blood and also the impure blood from the general body both to enter an undivided auricle, and this chamber is now partitioned into a right half and a left half which respectively receive the impure and pure blood. The ventricle, however, remains undivided, and the two kinds of blood partly mix within it, only the head (by means of a complex mechanism) receiving a supply of pure blood.

A reptile does not pass through a tadpole stage, but possesses a three-chambered heart much like that of an adult frog. In crocodiles, however, the heart is *four*-chambered, for the ventricle is divided into right and left moieties. But the pure and impure bloods are not kept entirely separate,

as they partially mix *outside* the heart. This is the result of blood passing from the heart into *paired* aortic arches, an essential feature of the fish type of circulation and correlated with the presence of gill-arches and gill-clefts. A fish or tadpole possesses several pairs of aortic arches, an adult frog three pairs, and a reptile at least one pair. In a crocodile the two members of the pair communicate at their bases.

A mammal achieves the *complete* separation of pure and impure blood by division of the ventricle and *suppression* of one of the two aortic arches present in the reptilian ancestors. The one which survives curves to the left, and is known as the *aorta*. The perfecting of the mammalian circulatory apparatus means that *all* parts of the body receive pure blood, which is *warm*, i.e. maintained at a constant temperature (about 98° F.), commonly higher than that of the surrounding air. This involves a more rapid cycle of chemical change (metabolism) in the body, leading to greater activity, and conferring a great advantage in the keen struggle for existence. Improved respiratory organs are associated with this advance. The perfecting of the circulation must be regarded as the *primary* factor concerned in conferring supremacy upon mammals.

3. During the vast period of time occupied by the evolution of mammals the brain has become relatively large and complex, in correlation with increasing intelligence. This line of advance, rendered possible by the improved circulatory and respiratory organs, and favoured by the habit of fostering the young, has confirmed the success of the group.

The features of the soft parts of Mammals just briefly described are associated with certain modifications of the hard parts. A reduction took place in the number of bones making up the skull; e.g. the lower jaw was reduced to *two* bones, and these acquired a *direct* attachment to the hinder parts of the brain-case. The single knob or condyle which in reptiles projects from the back of the skull, and fits into a cap in the front of the backbone, became divided into right and left halves, and so forth. The skeleton of the limbs also underwent various changes in relation to improved locomotion on a land surface, and the nature of these changes will be discussed in a subsequent chapter.

We also find typical and profound changes in the dentition. The numerous teeth of an average reptile are simple single-fanged cones, all much alike (*homodont*), and they are replaced from time to time by others throughout the whole of life (*polyphyodont*). Change from the reptilian to the mammalian condition involved: (*a*) reduction in number; (*b*) evolution of differently shaped *kinds* of teeth (*heterodont*), those at the back with more than one fang; (*c*) reduction in the number of successive sets.

Some of the Anomodont reptiles of the Permian and Trias periods strikingly resemble Mammals in the structure of their hard parts, so much so that the scanty and fragmentary Triassic fossils commonly referred to the Mammalia possibly belong to reptiles of this kind. We are at any rate justified in drawing the conclusion that these reptiles came very near the ancestral mammalian stock, and perhaps some of them were in the direct line of descent.

CHAPTER VIII

THE EVOLUTION OF ANIMALS IN GEOLOGICAL TIME—JURASSIC PERIOD

The Jurassic being the middle period of the three comprised in the Mesozoic epoch naturally gives the best idea of the typical animals belonging to that epoch. The stratified rocks of this period are exceedingly fossiliferous, and have been studied in great detail. They were the first to be worked out in England, the cradle of geological science. It is a fortunate circumstance that some of the Upper Jurassic strata of Bavaria and Würtemberg (lithographic stone of Solenhofen, &c.) are exceedingly fine-grained and admirably adapted to the preservation of fossil remains, while some of the Jurassic rocks of the United States have added greatly to our knowledge of the land life of the period. There is, however, no break in the succession. The Jurassic fauna is linked with that of the Palaeozoic by means of the organic remains of the Trias, and with that of the Kainozoic by the fossils of the Cretaceous.

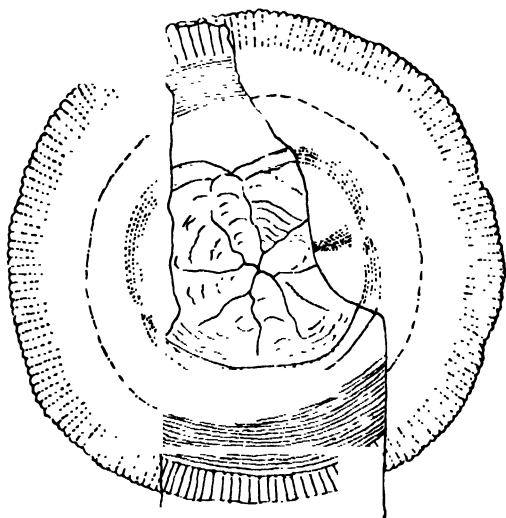


Fig. 305.—A Jurassic Jelly-fish (*Rhizostomites*), the missing parts dotted in ($\times \frac{1}{2}$). (After von Zittel.)

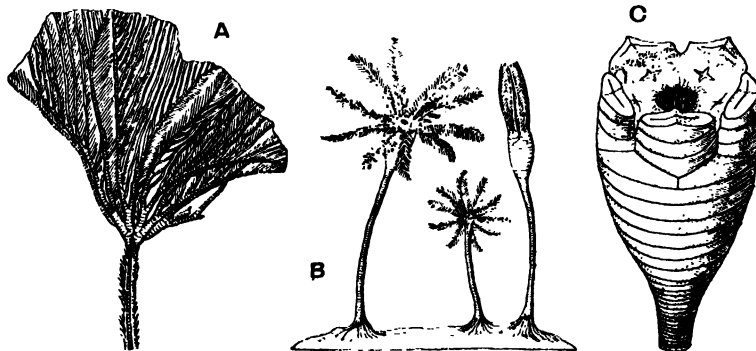


Fig. 306.—Jurassic Sea-lilies

A, *Pentacrinites* (reduced). B, Group of *Pelecypodites* (*Aptocrinites*), much reduced. C, Part of a *Pelecypodite* (reduced).

MARINE FAUNA.—Unicellular animals (PROTOZOA) are abundantly represented by the calcareous shells of Foraminifera and the siliceous ones

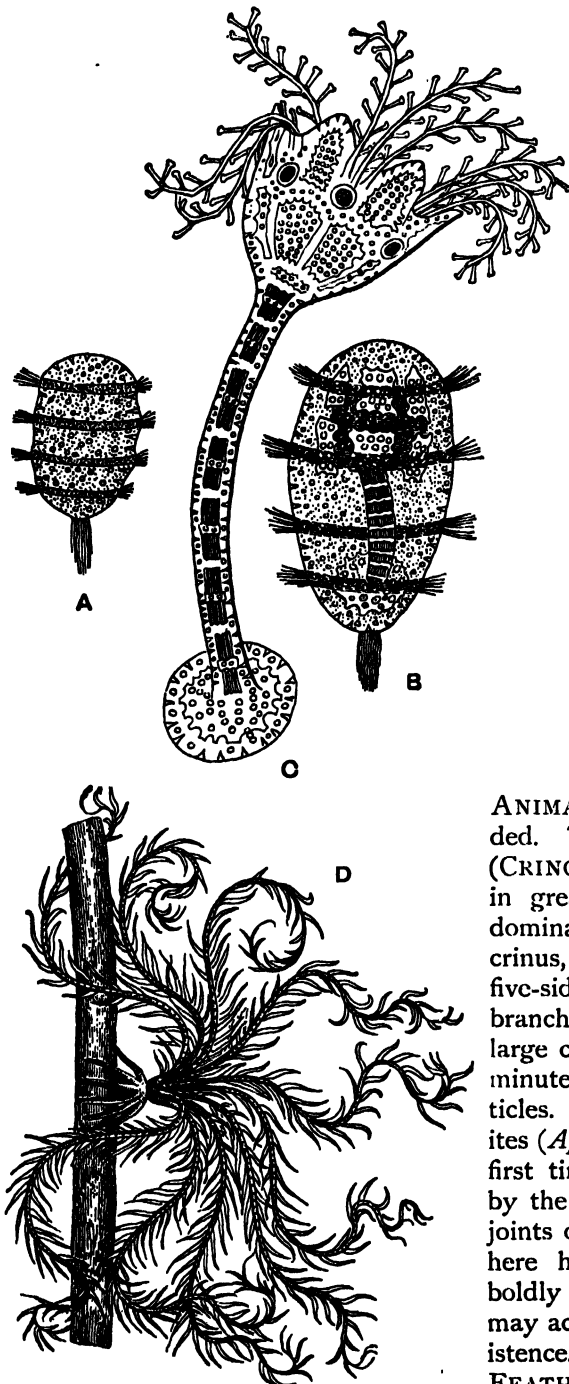


Fig. 307.—Feather-star (*Comatulæ*)

A, B, C, Stages in Development (enlarged). (After Thomson.)
D, Adult, anchored to a piece of seaweed.

of Radiolaria, while SPONGES (PORIFERA), both calcareous and siliceous, are common. But these present no points of general interest that need detain us.

HYDROID ZOOPIHYTES and JELLY-FISHES (HYDROZOA) are fairly well represented, impressions of the latter being found in the fine-grained Solenhofen rocks, so clearly outlined as to be susceptible of accurate classification (fig. 305). The numerous Jurassic limestones contain large numbers of CORALS (ANTHOZOA), many of which built up reefs and closely resembled the reef-builders of to-day. Some four families were here represented for the first time.

HEDGEHOG-SKINNED ANIMALS (ECHINODERMA) abounded. The old class of SEA-LILIES (CRINOIDS) (fig. 306), now existing in greatly reduced numbers, was dominated by such forms as *Pentacrinus*, in which the long stalk was five-sided, while the arms were richly branched, collectively presenting a large ciliated surface for capturing minute organisms and organic particles. The curious *Pear-enocrinites* (*Apiocrinidæ*) appeared for the first time, and were distinguished by the broadening out of the top joints of the stalk. We also note here how a decadent group, by boldly adopting a fresh way of life, may acquire a fresh tenure of existence. For we meet with the first FEATHER-STARS (fig. 307), Crinoids which abandoned their stalks, and reacquired the power of moving

from place to place. While at the present day Sea-lilies are rare and limited to the chilly abysses of the deep sea, Feather-stars are extremely common in shallower water. The life-history of one of the latter is of singular interest, being one of the best instances known illustrating the "recapitulation theory", according to which the history of an individual epitomizes the evolution of its group. For a feather-star, after living for

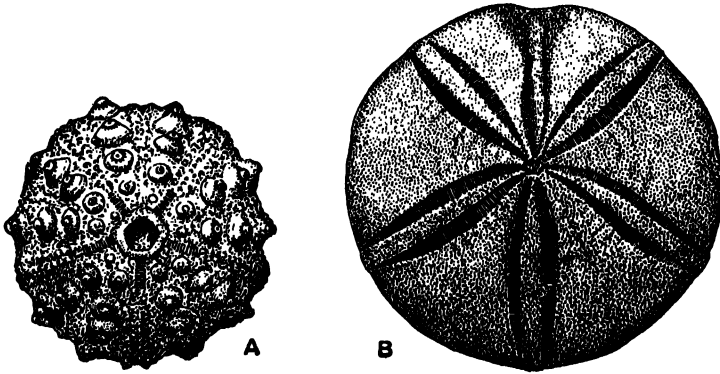


Fig. 308.—Jurassic Sea-urchins, seen from above

A, *Hemicidarid*, a regular form. B, *Clypeus*, an irregular form.

some time as a free-swimming larva, becomes a minute sea-lily, afterwards abandoning its stalk.

BRITTLE-STARS (OPHIUROIDS) and STARFISHES (ASTEROIDS), now the dominant Echinoderms, were well represented in the Jurassic, and among the latter are found representatives of the Sun-stars (*Solaster*, &c.) with a considerable number of arms. SEA-URCHINS (ECHINOIDS) abounded, and presented a comparatively modern aspect. They included not only

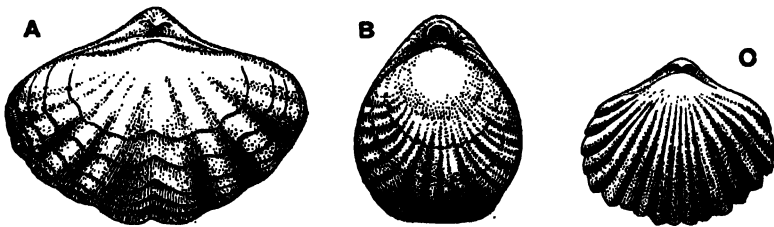


Fig. 309.—Jurassic Lamp-shells

A, *Spiriferina Walcottii*. B, *Terebratulina fimbriata*. C, *Rhynchonella tetrahedra*.

radially symmetrical or "regular" forms, but also bilaterally symmetrical or "irregular" types (fig. 308). The two-sided structure of the latter is an adaptation to movement in one definite direction, and evidently favours the securing of sufficient food, hence meaning success in the struggle for existence, for it becomes more and more marked to the present day.

MOSS-POLYPTES (POLYZOA) are common as Jurassic fossils, and so are LAMP-SHELLS (BRACHIOPODS). The latter were on the decline, and represented by comparatively few types, though numerous individuals.

Some of the archaic Palæozoic forms were here represented for the last time (*Spiriferina*, allied to *Spirifera*), but the vast majority (especially *Terebratula* and *Rhynchonella*) belonged to genera which still survive (fig. 309).

The most interesting point in regard to the marine CRUSTACEA is to be found in the comparative abundance of members of the highest group,

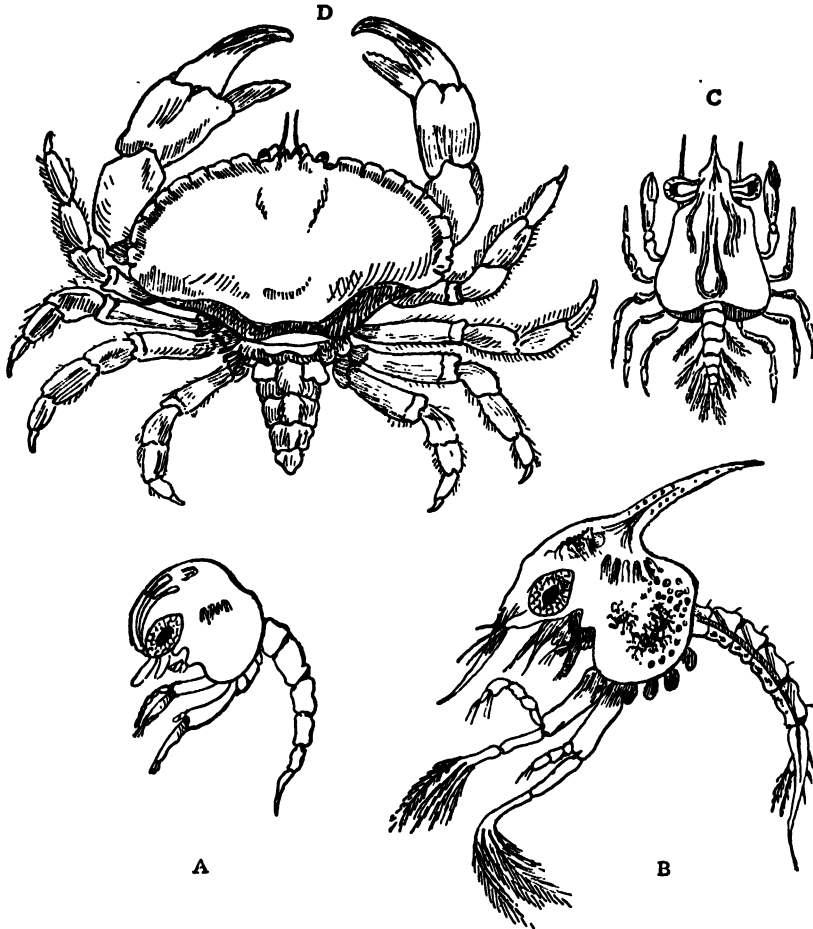


Fig. 310.—Life-history of Edible Crab (*Cancer pagurus*), enlarged

A, Young Zosæa. B, Fully formed Zosæa. C, Megalopa. D, Young Crab (during life the tail is bent up under body).

i.e. the LOBSTER ORDER (DECAPODA), particularly well represented in the Solenhofen rocks. They included the first known Crabs, very dominant forms at the present day. These are characterized by abandonment of the free-swimming habit, which has involved reduction of the tail and broadening of the front part of the body (fig. 310). Crabs, in short, have become the creeping scavengers of the sea. It is true that some of them have subsequently reacquired the swimming habit, broadening out their last pair of legs as paddles; but this is exceptional. The members of this

group represent the climax of Crustacean evolution, being more specialized, and therefore higher than any of their allies.

MOLLUSCS (MOLLUSCA) of all kinds abound in the Jurassic strata, and some of them play no unimportant part in building up limestones (fig. 311). Several families of BIVALVES (LAMELLIBRANCHIA) and many genera appeared for the first time. Some of these, *e.g.* Venus, Tellina, and Cyrena, become of increasing importance down to the present day; but throughout the whole of the Mesozoic epoch the competition of the Brachiopods was

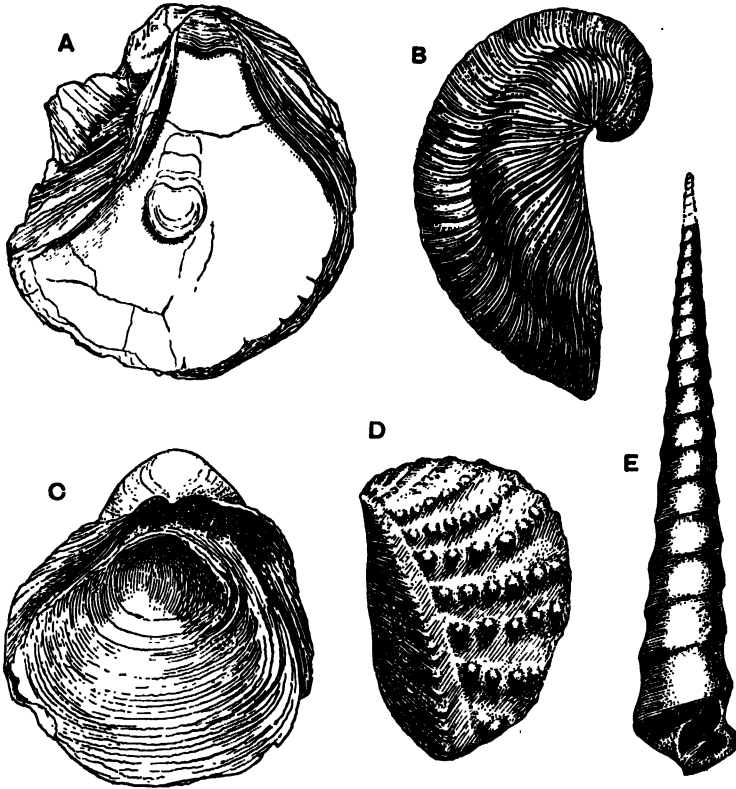


Fig. 311.—Jurassic Molluscs

A, *Ostrea deltoidea*. B, *Gryphæa incurva*. C, *Gryphæa dilatata*. D, *Trigonía clavellata*. E, *Nerinea*.

still formidable. Certain boring forms, such as *Pholas* and *Teredo* (the "ship worm"), made their first undoubted appearance, though possibly taking origin as far back as Carboniferous times. Among fixed bivalves oysters and their allies were represented by a profusion of species and a great wealth of individuals. Some are very characteristic of certain horizons. Among free bivalves the three-cornered *Trigonía*, a new genus, is extremely typical, and its numerous well-marked species greatly aid the task of establishing the smaller subdivisions of the Jurassic strata. It is interesting to notice that *Trigonía* is still represented by dwarfed species in Australian seas, this being one among many instances illustrating the archaic nature of the Australian fauna.

SEA SNAILS (GASTROPODS) were common, and we note the incoming of several families which occupy a prominent position in the marine life of to-day, such as those of which the pelican's-foot shell (*Aporrhais*), the stromb-shells (*Strombus*), the spindle-shells (*Fusus*), the cowries (*Cypræa*), and the bubble-shells (*Bulla*) are familiar types. Of families limited to Mesozoic times that including *Nerinea* is perhaps the most important.

Several interesting features are presented by the members of the highest group of Molluscs (CEPHALOPODS). Forms allied to *Nautilus* (nautiloids)

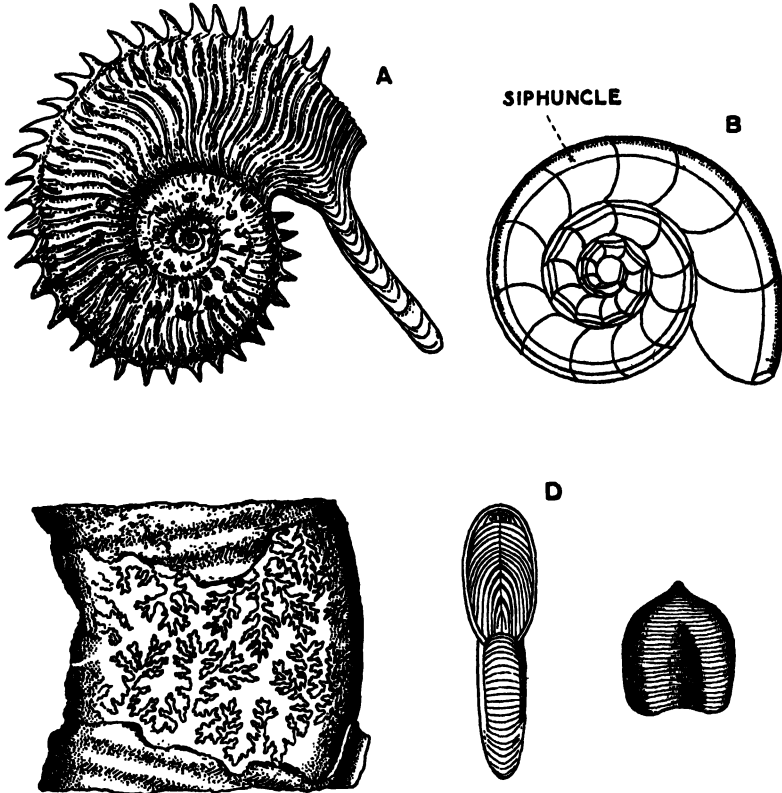


Fig. 312.—Structure of Ammonites

A, *Ammonites Jason*, to show rostrum. B, Ammonite in section, to show siphuncle (after Munier-Chalmas). C, Part of worn Ammonite, showing folded edges of the septa. D, Aptychus closing mouth of shell (after Owen). E, Anaptychus of *Amaltheus spinatus* (after von Zittel).

were greatly on the decline, and those which existed were closely rolled spirals. Ammonites, on the other hand, attained their maximum, and included a large variety of species (fig. 312). Three interesting structural features require mention, as they appear to be related to the mode of life. One is the drawing out of the back edge of the mouth of the shell into a beak or rostrum, possibly as a protective measure. It is precisely in this region that the *funnel* of *Nautilus* is situated, an organ consisting of two muscular flaps rolled together, and serving to forcibly expel water from the gill cavity, thus enabling the animal to swim backwards. The

possession of a rostrum by Ammonites suggests that the funnel had dwindled in size, with corresponding diminution of swimming powers.

The second characteristic feature consists in the elaborate folding of the edges of the partitions (septa) which bound the successive chambers of the shell. In the third place, we find that the shelly tube, or *siphuncle*, which places these chambers in communication, and contains a cord-like prolongation of the animal's body, is smaller than in nautiloids, and not central, but shifted towards the convex outer side of the shell. It would appear that the use of the siphuncle is to regulate the contents of the chambers, which collectively serve as a hydrostatic apparatus, and the reduction of this organ in Ammonites may be supposed to indicate less efficient swimming. "These facts and the gregarious littoral habits of Ammonoids show that they probably crawled along the bottom with their shells carried above them, very rarely swimming. Their shells are also less bulky in proportion than those of Nautiloids, and correspondingly less buoyant. All these observations justify the hypothesis that the progressive complication of Ammonoid sutures [*i.e.* edges of the septa] took place because of their utility in helping to carry and balance the shell above the extended parts when the animal was crawling" (von Zittel's *Textbook of Palæontology*, English edition, Vol. I, p. 544).

If we accept the plausible hypothesis that Ammonites had abandoned a swimming life for a crawling one, a reason for such a change of habit must be sought. This may well be found in the keen competition for food offered by swifter and better-armed swimmers, *i.e.* belemnites, cuttle-fishes, bony fishes, and marine reptiles. As these were not only rivals in the pursuit of animal food, but also active enemies, protective measures became necessary. Such were afforded by the stronger shell with its sharp rostrum, and also by a plate or *operculum* for closing the opening of the living chamber after retraction of its occupant. This plate was either horny and in one piece (*anaptychus*) or calcareous and double (*aptychus*).

Turning now to Cephalopods with internal shells, we find that belemnites, already present in the Triassic strata, attained their climax (fig. 313), while true cuttle-fishes made their first appearance. The shells of the latter are far less clumsy than those of belemnites, and adapted to more rapid swimming. Both groups possessed an ink-bag, the contents of which were ejected into the surrounding water when attacks were made or threatened by predaceous fishes and reptiles. It may be noted that some of the species of ammonites and belemnites have a restricted vertical range, *i.e.* were comparatively short-lived, and afford a valuable means of establishing small subdivisions (zones) of the Mesozoic strata.

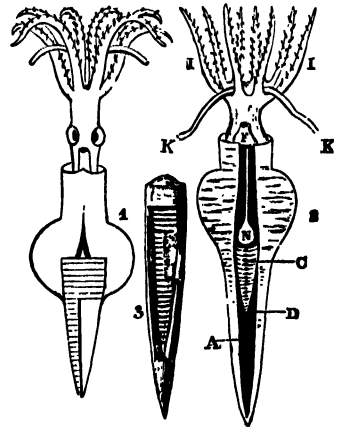


Fig. 313.—Belemnites (reduced)

1 and 2, Restorations. A, B, C, Internal shell. F, Funnel. I I, Short arms. K K, Long arms. N, Ink-bag. 3, Shell.

Among marine Jurassic fishes we find for the first time SHARKS and RAYS (ELASMOBRANCHIIS) of modern kind. The latter are flattened from above downwards as an adaptation to lurking on the sea floor in wait for prey, and the pectoral fins are greatly enlarged as swimming organs. The Jurassic types (*Squatina* and *Rhinobatus*), which persist to the present day (fig. 314), exhibited the beginning of this kind of specialization, and may be regarded as ancestral rays.

FRINGE-FINNED FISHES (CROSSOPTERYGII) were markedly on the decline, but were represented by marine species, while at the present day their last descendants (*Polypterus* and *Calamoichthys*) survive in some of the

African rivers. RAY-FINNED FISHES (ACTINOPTERYGII), on the other hand, were more numerous, and some of them were acquiring those distinctive features—*i.e.* loss of armour, ossified internal skeleton, and symmetrical tails—which have led to success in marine life (fig. 315). The more primitive groups of this order included primeval sturgeons (*Chondrosteus*, &c.) and a very dominant Jurassic type represented by armoured forms (*Lepidotus*, *Dapedius*, *Mesodon*, *Eugnathus*), and also by species with thin overlapping scales. Some of the latter (*Pachycormus*, &c.) were over a yard long, and “as completely adapted for a predaceous life in the open sea as the modern sword-fishes” (Smith Woodward, *Vertebrate Palaeontology*, p. 109), while others (*Megalurus*) only differed in detail from the bow-fin (*Amia*) now living in North American lakes. A related armoured group beginning in the Jurassic (*Aspidorhynchus*, &c.)

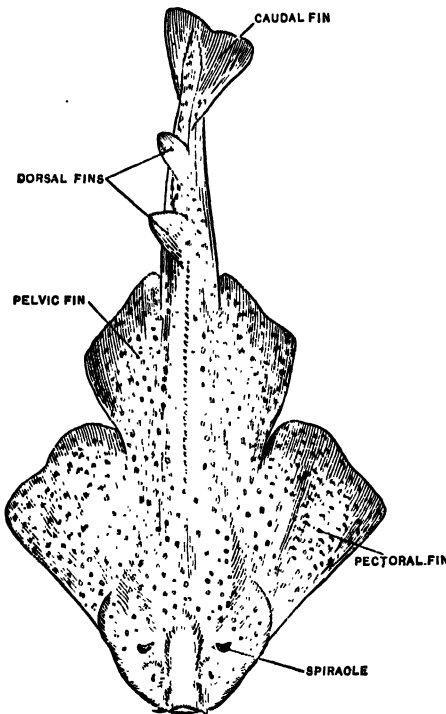


Fig. 314.—*Rhinobatus*

is now solely represented by the bony pike (*Lepidosteus*) of the same lakes.

The ray-finned fishes so far mentioned, together with the fringe-finned types, are popularly termed “Ganoids”, while the rest of the ray-fins are similarly named “Teleosts”, which include such recent forms as herring, perch, and cod, and are distinguished by a high degree of adaptation to rapid swimming. The features which promote this are: (*a*) shape of body resembling a rounded wedge; (*b*) flexible overlapping scales and slimy skin, which reduce friction and make lateral undulations easy; (*c*) well ossified internal skeletons, affording a firm support to the body, and furnishing strong points of attachment for swimming muscles; (*d*) externally symmetrical (homocercal) tail-fin, serving as a propeller and enabling straight-ahead swimming without steering. Herring-like types of the kind began

to appear in the Upper Trias, and became more numerous in Jurassic times (*Leptolepis*, *Thrissops*, &c.).

Turning now to Jurassic marine REPTILES, we find (fig. 316) the large swan-necked *Plesiosaurus* (up to 16 ft. long or more) and its gigantic

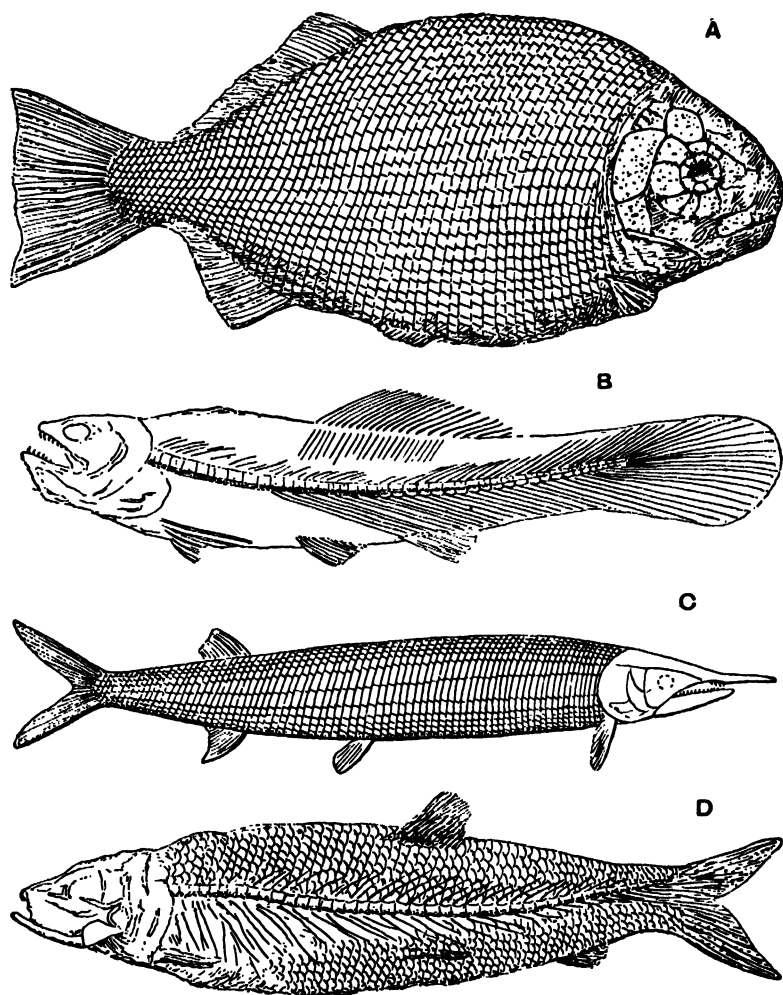


Fig. 315.—Jurassic Fishes

A, *Dapedius*. B, *Megalurus*. C, *Aspidorhynchus*. D, *Leptolepis*.

short-necked ally *Pliosaurus*, together with the porpoise-shaped *Ichthyosaurus*, some species of which were over 32 ft. long (fig. 317). In all these types the fore and hind limbs were powerful paddles. Several structural features of *Ichthyosaurus* are of special interest. The long crocodile-like jaws, with their strong, pointed teeth, indicate a predaceous mode of life, and the large eyes, supported by bony plates, point to a nocturnal habit. A row of unpaired fins on the back, unsupported by hard structures, helped to balance the body, and there was a powerful vertical tail fin as

a propeller. The lower lobe of this fin was larger than the upper, enabling the animal to move obliquely upwards to the surface by unsteered swimming. This arrangement had reference to air-breathing. Ichthyosaurs no doubt sprang from a terrestrial stock, and resemble the extinct

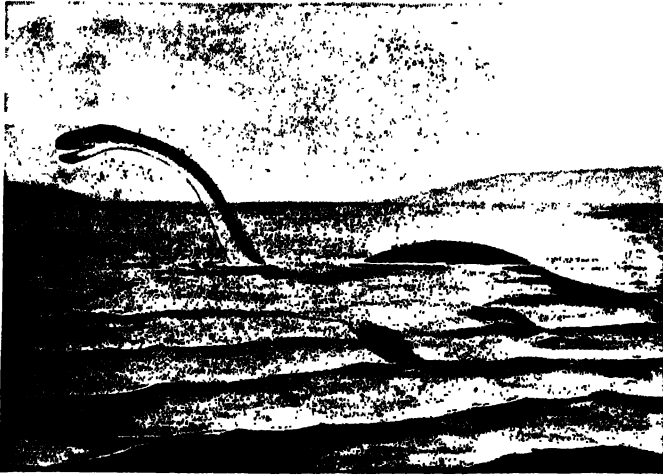


Fig. 316.—Restoration of Plesiosaurus. (From Sir E. Ray Lankester.)

armoured Amphibia (Stegocephala) in the structure of their teeth and backbone, which suggest a clue to their descent.

TOOTHLESS REPTILES (CHELONIA) were fairly common in Jurassic times, and some of them appear to have been marine. Most of the Jurassic CROCODILES were entirely aquatic, and some of them (*Teleosaurus*, &c.) were purely marine. The internal openings of the nose were farther back than in Triassic types (fig. 318).

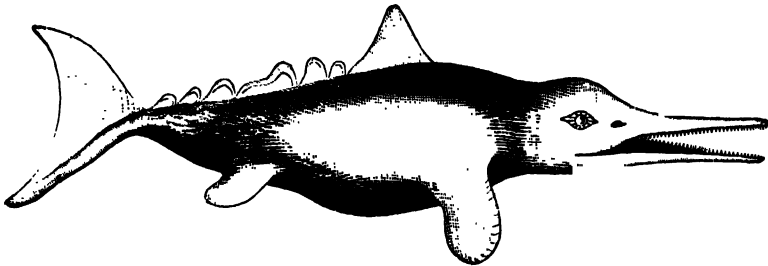


Fig. 317.—Restoration of Fish-Lizard (*Ichthyosaurus*), much reduced (after Fraas).

FRESHWATER AND ESTUARINE FAUNA (fig. 319).—Some of the freshwater Jurassic strata are crowded with little MUSSEL-SHRIMPS (OSTRACODA) enclosed in bivalve shells (*Cypridea*, &c.). The SLATERS (ISOPODS) were represented by forms (*Archæoniscus*), which may perhaps be described as water wood-lice, and the TEN-LEGGED CRUSTACEA (DECAPODS) included crayfishes.

Beautifully preserved DRAGON-FLIES (ODONATA) are found in the

Solenhofen stone (*Petalia*, *Aeschna*, &c.), and there is no reason to doubt that they hatched out as larvæ living in fresh water.

MOLLUSCS were represented by freshwater mussels (*Unio*) and other bivalves (*Cyrcna*), river-snails (*Paludina*), and air-breathing pond-snails (*Physa*, *Limneus*, *Planorbis*), these latter appearing for the first time.

Certain Jurassic FISHES lived in the waters of the land. They included

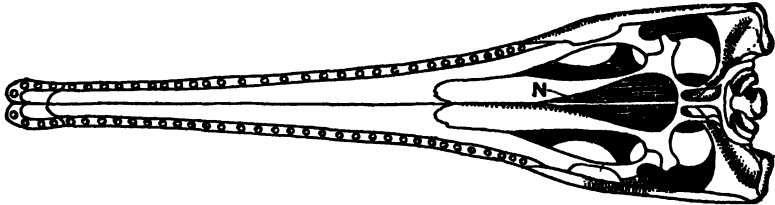


Fig. 318.—Under side of the skull of a Jurassic Crocodile (*Pelagosaurus*). N, Internal nares.

lung-fishes (*Ceratodus*), "Ganoids" (species of *Megalurus* and *Aspidorhynchus*), and some of the forerunners of the "Teleosts". Lung-fishes were driven from the sea by pressure of competition during the Triassic period, and the Ganoids were clearly beginning to take refuge in estuaries, rivers, and lakes during Jurassic times.

Jurassic REPTILES appear to have included freshwater tortoises, and some small broad-nosed freshwater crocodiles appeared at the end of the

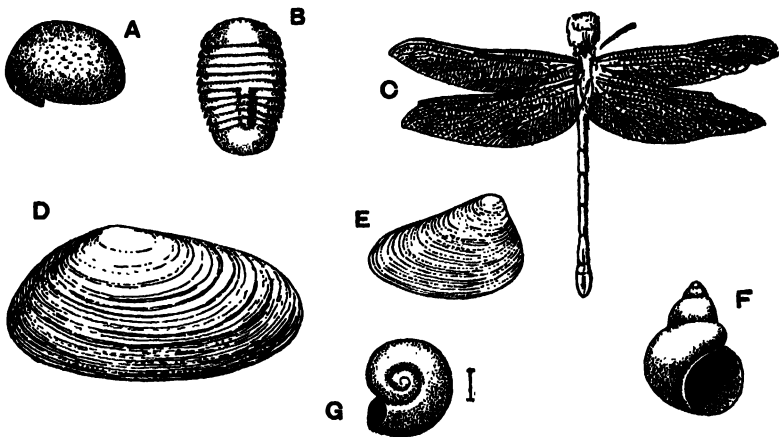


Fig. 319.—Jurassic Freshwater Invertebrates

A, Cypridea ($\times 15$). (After von Zittel.) B, Archæoniscus. C, A Dragon-fly (*Petalia*), the larva of which no doubt lived in fresh water. D, *Unio*. E, *Cyrcna*. F, *Paludina*. G, *Planorbis*.

period. "It has been suggested that the appearance of the broad-nosed genera in the Purbeck [late Jurassic] and Wealden [early Cretaceous] is correlated with the incoming of warm-blooded prey, whether mammalian or avian. It is, at any rate, curious that dwarf crocodiles of this kind (*Theriosuchus*, *Nannosuchus*) are associated with the remains of diminutive mammals in a stratum of the Purbeck beds near Swanage" (Smith Woodward, *Vertebrate Palæontology*, p. 218).



Fig. 390.—Photograph of the thigh-bone of the great extinct reptile *Atlantosaurus*, from the Jurassic rocks of the United States of America. (From Sir E. Ray Lankester.)

LAND FAUNA.—SCORPIONS and SPIDERS (ARACHNIDS) and their allies, as well as CENTIPEDES and MILLIPEDES (MYRIAPODS), undoubtedly figured in the land life of Jurassic times, but their remains are extremely scanty. Of INSECTS, Flies (DIPTERA), the most highly specialized members of the class, appeared for the first time, and all the other orders were represented, except the moths and butterflies (LEPIDOPTERA). LAND-SNAILS (GASTROPODS) existed, but their shells are not abundant.

The dominant Jurassic land animals were REPTILES, nearly all of these belonging to extinct orders, and many of huge size. Of BEAKED REP-

TILES (RHYNCHOCEPHALA), we find small forms (*Homoiosaurus*) closely resembling the existing Tuatara (*Hatteria*) of New Zealand. Some fragmentary remains (*Macellodus*) from the uppermost Jurassic strata are doubtfully referred to the order of LIZARDS (LACERTILIA). Most important, however, are the DINOSAURS, which first appeared in Triassic times. Of these Sir E. Ray Lankester says: "They are a varied group, and mostly were of great size. They seem to have occupied in many ways the same sort of place on the earth's surface which was filled at a later period by the great mammals, such as elephants, rhinoceroses, giraffes, giant kangaroos, &c. Preying on the vegetable-feeding kinds there were huge carnivorous dinosaurs, representing the lions and tigers of to-day. Yet the mammals I have mentioned are in no way descended from these great reptiles. They



Fig. 321.—Probable appearance during life of *Diplodocus* and similar Dinosaurs. (From Sir E. Ray Lankester.)

came from another stock, and only superseded them on the face of the earth by a slow process of development, in which the great reptiles disappeared and the great mammals gradually appeared and took their place" (*Extinct Animals*, pp. 192-4). The order is subdivided into three groups, the first of which is represented in the Triassic strata, while the species belonging to the other two first appear in the Jurassic period. These groups are: 1, Beast-footed Dinosaurs (Theropods); 2, Reptile-footed Dinosaurs (Sauropods); 3, Bird-footed Dinosaurs (Ornithopods).

BEAST-FOOTED DINOSAURS (THEROPODS) were predaceous forms with sharp-edged teeth contained in sockets. Their fore limbs were short, and they walked about on the ends of their elongated toes. One formidable Jurassic type (*Megalosaurus*) had its head raised about 9 ft. from the ground when the bipedal position was assumed, another larger form (*Ceratosaurus*) had an unpaired horn on its nose, and one small kind (*Hallopus*) seems to have progressed by leaps like a kangaroo.

REPTILE-FOOTED DINOSAURS (SAUROPODS) were strongly built herbivorous forms which walked on all-fours, resting on the palms of the hands and soles of the feet. Some of them were larger than any other

known land animals, the biggest being an American form (*Atlantosaurus*) that possessed thighbones 6 ft. long, as compared with 4 ft. for the largest elephants (fig. 320). Somewhat smaller American types (*Brontosaurus* and *Diplodocus*) were over 60 ft. long, and they possibly prowled about in estuaries and shallow seas with most of the body submerged (fig. 321).

BIRD-FOOTED DINOSAURS (ORNITHOPODS) were vegetarian forms of varying size. Some of the Jurassic types (*Laosaurus*) were bipedal, while others progressed on all-fours. The most remarkable of these were armoured, one well-known American form (*Stegosaurus*), about 29 ft. long, bearing a series of large plates and spines along the middle of its back (fig. 322).

During Jurassic times Reptiles, already dominant in the sea and on



Fig. 322.—Probable appearance in life of the Jurassic Dinosaur *Stegosaurus*. The hind leg alone is twice as tall as a well-grown man. (From Sir E. Ray Lankester.)

land, also assumed the sovereignty of the air. We find, in fact, an order of FLYING REPTILES (ORNITHOSAURS) with well-developed membranous wings stretched between the limbs and the sides of the body, their outer edges being supported by the greatly elongated little fingers (fig. 323). Other membranes extended between the hind limbs and tail. One typical long-tailed form (*Ramphorhynchus*) had a spread of wing of about 28 in., and there were also smaller short-tailed forms (Pterodactyles). As the wings are completely developed in the oldest known flying reptiles, we can only guess at the way in which they have arisen. There are certain recent Lizards in which the skin is drawn out at the sides of the body into folds employed as parachutes to aid descent from branch to branch of a tree or from a tree to the ground. This suggests that the wings of the flying reptiles were evolved from similar folds.

The reptiles just mentioned became extinct by the end of the Mesozoic epoch, but the dominant flying backboneed forms of to-day, *i.e.* BIRDS, are first known from the Jurassic period, though no doubt they existed pre-



Fig. 323.—Probable appearance in life of two kinds of Jurassic Pterodactyles (*Dimorphodon* and *Rhamphorhynchus*). (From Sir E. Ray Lankester.)

viously. Only one type (*Archæopteryx*) has so far been discovered, a bird about the size of a rook, beautifully preserved in the lithographic stone of Solenhofen (fig. 324). This bears unequivocal marks of reptilian descent in its long tail, conical teeth, and three claw-bearing digits of the fore limb. But its general build, feathers, and wings prove it to be a bird. There is no reason to doubt that it was a hot-blooded animal, with a four-chambered heart in which the pure and impure blood were kept separate, a single aortic arch (turning to the *right*, not to the left as in Mammals), and improved breathing organs. Its brain was also much larger than that of the contemporary flying reptiles. These, indeed, proved quite unable to contest the sovereignty of the air with birds and bats. The reptilian stock which gave origin to birds probably included climbing forms, possibly relatives of the bipedal Triassic Dinosaurs, which

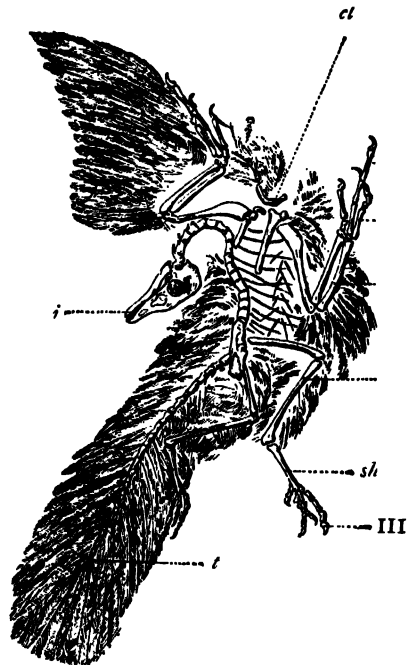


Fig. 324. —Extinct Toothed Bird (*Archæopteryx*)

j, Toothed jaws; *cl*, collar-bone; *u*, ulna; 2 and 3, second and third fingers; *s*, shin-bone; *sh*, shank-bone; *III*, third toe; *t*, axis of tail.

first acquired parachutes and then wings. These, however, are quite unlike the membranous wings of flying reptiles and bats, their essential parts being quill feathers attached to the fore limbs, in which the digits are reduced to three, and a good deal of fusion has taken place, so that a firm support to the feathers is constituted.

MAMMALS, indicated by unsatisfactory fragments in Triassic rocks, are represented by a number of small forms that existed during various stages of the Jurassic period (fig. 325). Taking recent members of the class as a

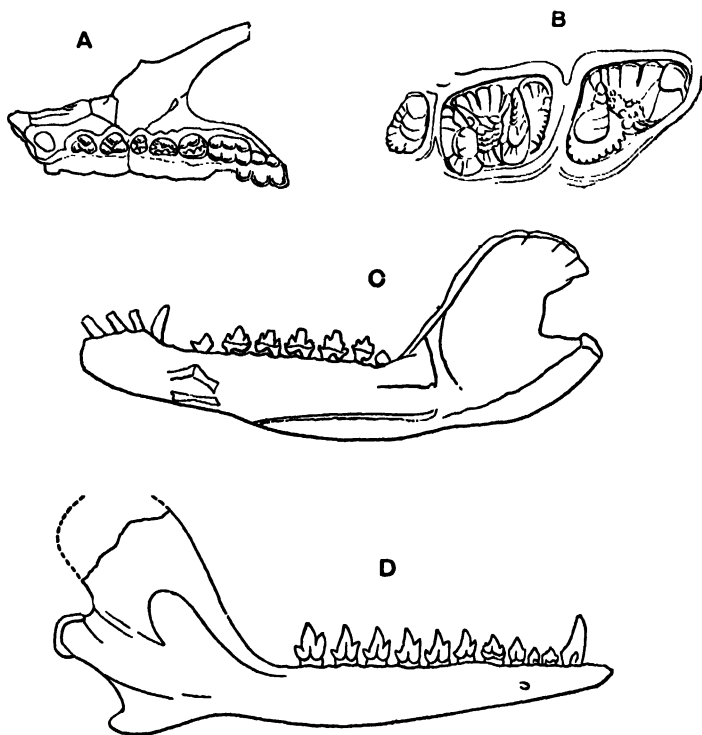


Fig. 325.—Jurassic Mammals (all enlarged). (After Marsh.)

A, Part of upper jaw of Allodon. B, Temporary grinding teeth of existing Duck-mole (*Ornithorhynchus*) for comparison. C, Lower jaw of Phascolotherium. D, Lower jaw of Dicrocynodon.

basis, three subdivisions may be recognized: 1, Egg-laying Mammals (Prototheria); 2, Pouched Mammals (Metatheria); 3, Higher Mammals (Eutheria).

EGG-LAYING MAMMALS (PROTOTHERIA) are now only represented by the Spiny Ant-eaters (*Echidna* and *Proechidna*) and Duck-mole (*Ornithorhynchus*) of the Australian region. The former are toothless, while the latter possesses horny plates in the adult condition, replacing minute teeth with crowns bearing small tubercles. Some of the Jurassic strata contain the lower jaws of very small Mammals (*Plagiaulax*, *Allodon*, &c.) with teeth resembling in character the transient ones of the Duck-mole, and indicating a close affinity (fig. 325, A, B).

Other small jaws of Jurassic date (*Phascolotherium*, *Dicrocynodon*, &c., fig. 325, C, D) appear to belong to Pouched Mammals (METATHERIA).

These early Mammalian remains give but an unsatisfactory idea of the first stages in the evolution of the class, which perhaps took place on a southern continent now for the most part submerged, but partly represented by island fragments with, possibly, the Antarctic land mass. It may be that, in course of time, these areas will furnish materials for working out in more or less detail the first stages in the development of Mammals from a primeval reptilian stock.

CHAPTER IX

THE EVOLUTION OF ANIMALS IN GEOLOGICAL TIME—CRETACEOUS PERIOD

In the preceding chapters a brief account has been given of the rise of all the great classes of animals possessing parts susceptible of preservation in the fossil state, and of many subdivisions of those classes. A large number of dominant Mesozoic groups died out in the Cretaceous period, while others appeared that only attained their full development in the succeeding Kainozoic epoch. There is, however, a great lack of the material necessary to fully trace the history of many groups which then became predominant, and this is particularly true for land vertebrates.

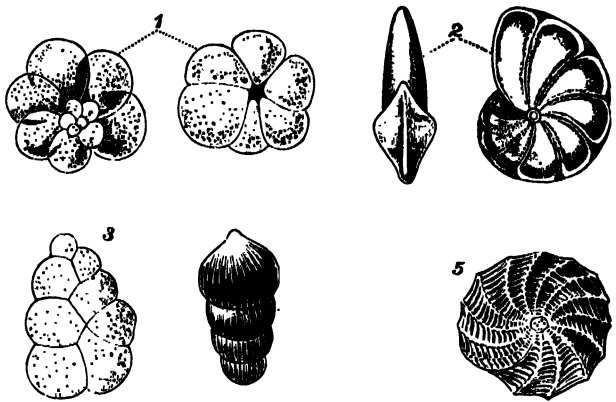


Fig. 326.—Shells of Foraminifera (enlarged)

1, Globigerina. 2, Cristellaria. 3, Textularia. 4, Nodosaria.
5, Polystomella.

MARINE FAUNA.—

The thick masses of chalk which make up a considerable part of the Upper Cretaceous over a large area essentially consist of a soft pure limestone, very largely composed of the shells of FORAMINIFERA closely resembling those which abound in the calcareous mud (foraminiferal ooze) that covers so large a portion of the floor of existing oceans (fig. 326). Such remains are more or less common all through Cretaceous rocks, and many of the grains which in some areas compose the Upper Greensand that lies beneath the chalk are internal casts in a green siliceous mineral (glauconite) of the shells of Foraminifera. The siliceous skeletons of RADIOLARIA are also fairly common in strata of this period.

SPONGES both calcareous and siliceous were very common (fig. 327), and it is noteworthy that the latter play an important part in building up the

flint nodules which are so marked a feature of the Upper Chalk. Corals related to the HYDROID ZOOPHYTES (HYDROZOA) made their first appearance in the Upper Cretaceous. SIX-RAYED CORALS (HEXACORALLA) were well represented, and many of them built up reefs. EIGHT-RAYED CORALS (OCTOCORALLA) were also not uncommon, and some of them be-

longed to well-known recent types, as sun-coral (*Heliopora*) and red coral (*Corallium*).

SEA-LILIES (CRINOIDS) were still on the decline. One peculiar stalkless species (*Marsupites*) resembles a fir cone in appearance (fig. 328). The closely related FEATHER-STARS were on the increase. BRITTLE-STARS (OPHIUROIDS) and ordinary STAR-FISHES (ASTEROIDS) were both increasing in importance, though

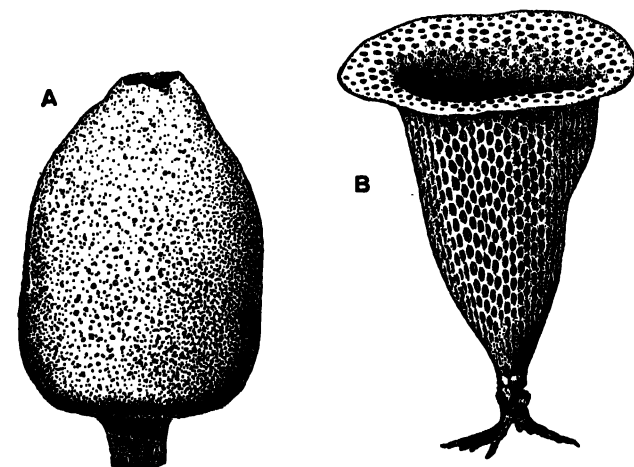


Fig. 327.—Cretaceous Sponges

A, *Siphonia*, stalk omitted. B, *Ventriculites*.

scarcely abundant. SEA-URCHINS (ECHINOIDS), both regular and irregular, formed a marked feature of the Cretaceous marine fauna (fig. 329).

MOSS-POLYPS (POLYZOA) are extremely numerous in some Cretaceous strata, especially in the Upper Chalk; but LAMP-SHELLS (BRACHIOPODS) were important for the last time, and clearly succumbing to the competition of bivalve molluscs and certain other forms.

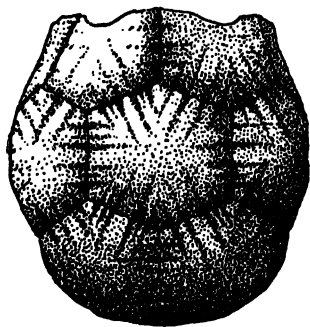


Fig. 328.—Cup of *Marsupites*

CRUSTACEANS require no special mention. The chief point to notice is the increased importance of the higher forms (Decapoda), both lobster- and prawn-like types, and their short-tailed relatives the Crabs.

BIVALVE MOLLUSCS (LAMELLIBRANCHIA) were very numerous and of increasing dominance. Several new families made their first appearance, including those represented by the scaly oysters (*Chama*), razor-shells (*Solen*), and stone-borers (*Saxicava*). There were also some extraordinary forms, peculiar to the Cretaceous, with the two valves of very unequal size. Of

these the horsetail shell (*Hippurites*) may be taken as an example (fig. 330). Here there is a pointed lower valve drawn out into a long cone, with a concavity above, which contained the soft body of the animal. The upper valve forms a kind of lid. These valves are really right and left, though it is not possible to say which is which. These peculiarities

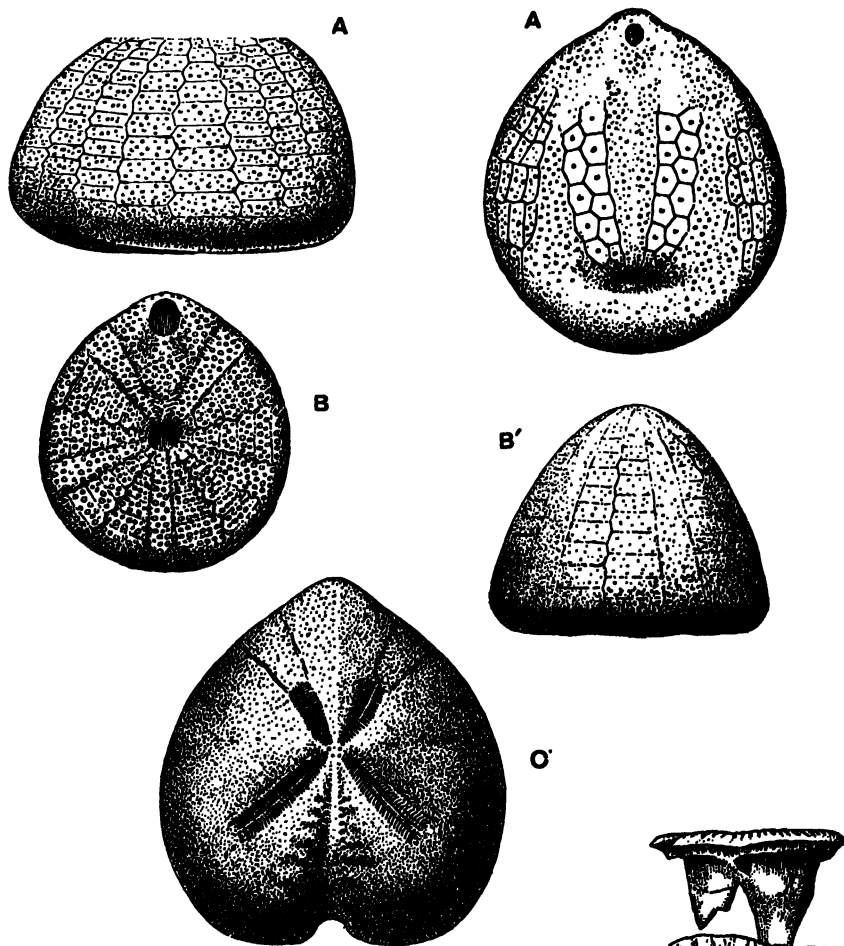


Fig. 329.—Cretaceous Sea-urchins

A and A', Echinocorys (*Ananchytes*), from the side and from below. B and B', Echinoconus (*Galerites*), from below and from the side. In A' and B the upper opening is the anus and the lower one the mouth. C, Top view of *Micraster*.

had reference to the soft calcareous mud in which the creatures lived, the lower valve serving as a sort of stalk, and preventing the mollusc from being smothered.

SEA-SNAILS (GASTROPODS) were particularly abundant, and began to assume a modern aspect. Some of the older families made their last appearance (*e.g.* those represented by *Euomphalus*, *Purpurina*, and *Nerinea*), while quite a number of carnivorous types, with the mouth of the shell notched or drawn out into a tube (*siphon*), are met with for the first time. Such are the families represented by helmet-shells (*Cassis*), tritons (*Tritonia*), whelks (*Nassa*), pear-shells (*Pyrula*), murices

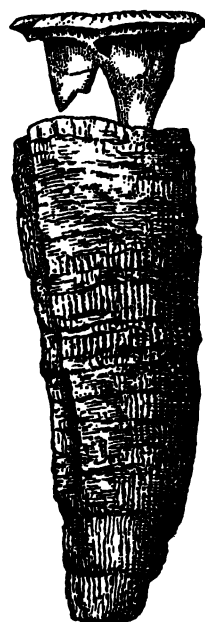


Fig. 330.—Hippurites

(*Murex*), purple-shells (*Lysis*), volutes (*Volutilithes*), olives (*Oliva*), cross-rib shells (*Cancellaria*), side-slit shells (*Pleurotoma*), and cones (*Conus*). At the present day the floating life of the sea (*plankton*) partly consists of shoals of little wing-footed snails (Pteropods), often popularly termed "sea butterflies", and in many species possessed of transparent glassy shells of various shape. Swimming is effected by means of two muscular wing-like flaps. These highly specialized forms, derived from various groups of sea-snails more or less unrolled, so as to bring the gill behind the heart (*Opisthobranch*, i.e. "hind-gilled"), are first met with in Cretaceous strata (fig. 331).

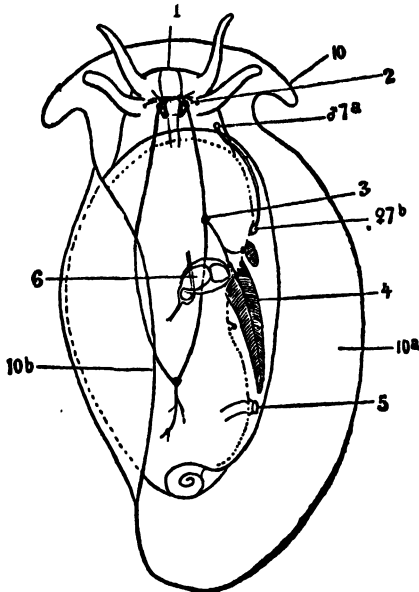


Fig. 331.—Diagram of Hind-gilled Snail, seen from above

1, Mouth; 2, nerve-ring with ganglia; 3, one of the two ganglia on the untwisted nerve-loop; 4, gill, just in front of which is seen an organ of smell; 5, opening of intestine; 6, heart in pericardium; 10, 10a, right swimming flap; 10b, left ditto folded over back. (After Lang.)

Extremely interesting are the members of the last group of Molluscs (CEPHALOPODS). Nautilus-like forms still persisted in diminished numbers, and Ammonites appeared for the last time. Some of these last are more or less unrolled (*Scaphites*, *Ancylloceras*, *Hamites*), and even become perfectly straight (*Baculites*), thus reversing the original stages by which the straight, chambered shell passed into a closely rolled spiral (fig. 332). In one type (*Turritiles*) the shell has become a screw-like spiral, as in many sea-snails. There was also a tendency to the production of spines and excessive ornament, as in many decadent groups.

Belemnites still existed, but in greatly diminished numbers. Though very rare, they are even found in the early Tertiary strata. Partly correlated with the wane of other Cephalopods, we find cuttle-fishes proper on the increase.

FISHES continued to evolve during Cretaceous times on the lines already

described, and towards the end of the period present a comparatively modern appearance. SHARKS and RAYS (ELASMOBRANCHS) closely allied to those now living came into existence, but Ganoids greatly diminished in number, while Teleosts increased proportionately. One genus (*Diplomystus*) differed but little from that to which the herring belongs, while eels and sea perch (*Hoplopteryx*) were both represented (fig. 333).

Among REPTILES, Plesiosaurs (*Cimoliosaurus*), Pliosaurus (*Polyptichodon*), and Ichthyosaurs (*Ichthyosaurus*) were the last representatives of their kind. On the other hand, Cretaceous rocks contain the remains of marine reptiles belonging to two groups peculiar to this period. The more remarkable of these (PYTHONOMORPHS) seem to have taken the place of the older marine reptiles, and were widely distributed, their remains having been found in Europe, both Americas, and New Zealand. The

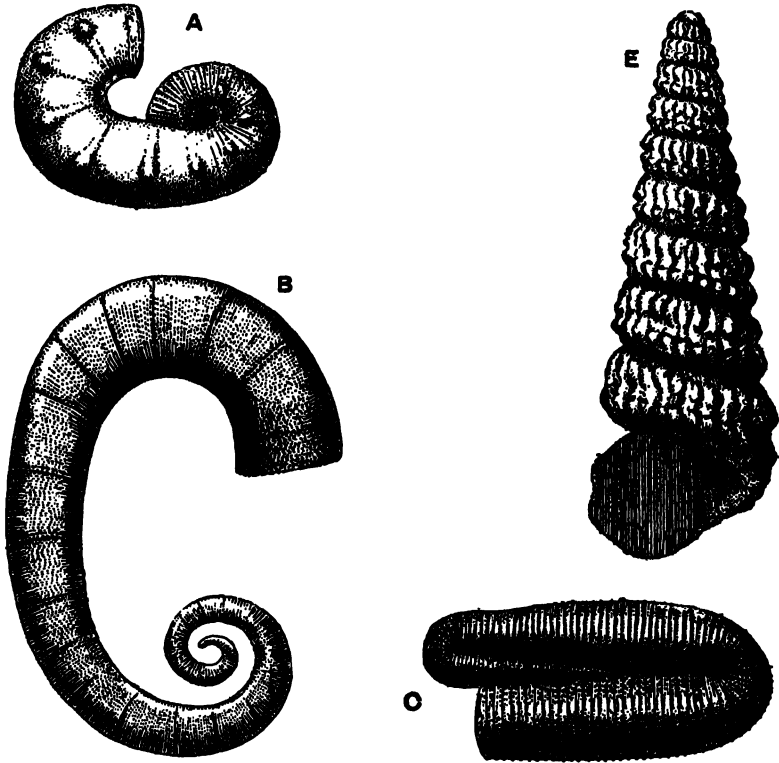


Fig. 332.—Decadent Cretaceous relatives of the Ammonites

A, Scaphites. B, Ancyloceras. C, Hamites. D, Baculites. E, Turritites.

largest known species (*Mosasaurus campeii*) possessed a lizard-like head, narrow body, and paddle-shaped limbs. It is believed to have sometimes attained the length of about 48 ft. (fig. 334).

Various TOOTHLESS REPTILES (CHELONIA) are found in the rocks of

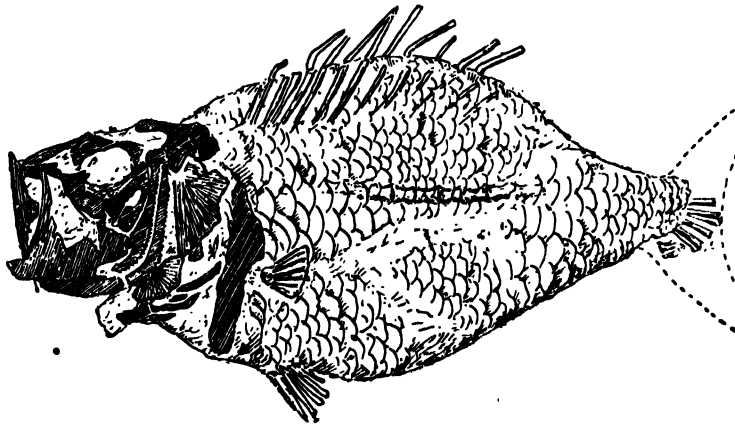


Fig. 333.—Cretaceous Sea-perch, *Hoplopteryx* (*Beryx*)

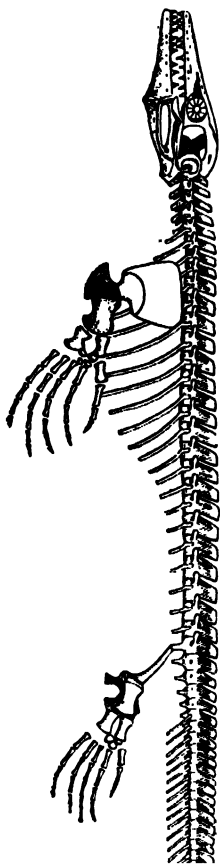


Fig. 334.—Skeleton of a Mosasaurian Reptile. (After Williston.)

the period. Some from the Upper Cretaceous belong to the same genus (*Chelone*) as the well-known Edible Turtle of recent seas, and one Italian species (*Protosphargis veronensis*), with a shell 9 ft. long, closely resembled existing Leathery Turtles (*Sphargis*). A similar gigantic form has been found in the American Cretaceous. The archaic BEAKED REPTILES (RHYNCHOCEPHALA) existed as large aquatic forms (*Champsosaurus*).

FRESHWATER AND ESTUARINE FAUNA.—Minute MUSSEL-SHRIMPS (OSTRACODS) were abundantly represented (*Cypridea*), and among the TEN-LEGGED CRUSTACEA (DECAPODS) we find crayfishes, some of which belong to the same genus (*Astacus*) as the common British species of to-day.

BIVALVE MOLLUSCS (LAMELLIBRANCHIA) were common, and included freshwater mussels (*Unio*) and other types (*Cyrcna*, *Cyclas*). *Cyclas*, a familiar little bivalve in recent times, first appeared in the Upper Cretaceous.

FRESHWATER SNAILS (GASTROPODS) were represented by some of the same genera (*Limnæa*, *Planorbis*, *Paludina*) as those characteristic of Jurassic times, and also by members of new families. One of these (represented by *Bythinia* and *Hydrobia*) contains only lung-bearing forms, but the apple-snails (*Ampullaria*), that live in fresh or brackish water, are also represented. These are remarkable in possessing both a gill and a lung cavity, so can breathe either air dissolved in water or ordinary air.

The REPTILES included freshwater tortoises, and there are some fragmentary remains in the Lower Cretaceous (and uppermost Jurassic) that have been referred to crocodiles of modern type. If this conjecture be correct, the internal openings of the nose were very far back (cp. p. 144).

LAND FAUNA.—MILLIPEDES (MYRIAPODS) were represented (*Julopsis cretacea*) and some INSECTS have been found, but the nature of the strata is unfavourable to the preservation of such remains.

LAND SNAILS (GASTROPODS) were sparsely present (*Megaspira*, *Glandina*, *Lychnus*), but the last remark applies to these also.

A newt-like form (*Hylæobatrachus*), probably with persistent gills, has been discovered in the Lower Cretaceous of Belgium, and is the oldest known example of AMPHIBIA of recent type.

The land REPTILES are of much interest, for several dominant Meso-



Fig. 335.—Probable appearance of the Iguanodon in its living condition. (From Sir E. Ray Lankester.)

zoic groups made their last appearance. Such were the REPTILE-FOOTED DINOSAURS (SAUROPODS), resembling those of the Jurassic period, and the



Fig. 336.—Drawing of the appearance in life of the Three-horned Dinosaur, *Triceratops* (after a model issued by the American Museum of Natural History). This reptile was of the size of the largest living rhinoceros. (From Sir E. Ray Lankester.)

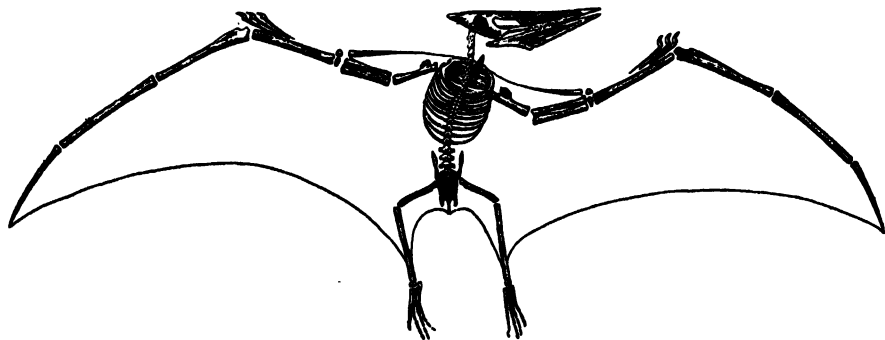


Fig. 337.—Drawing of a Restoration of the skeleton of the great Pterodactyle (*Pteranodon*) in the British Museum (Natural History). The stretch of the wings from tip to tip is eighteen feet. The bones of the fore limbs are natural; the rest of the body is restored from other specimens.

BIRD-FOOTED DINOSAURS (ORNITHOPODS). The most remarkable among the latter was a gigantic form (*Iguanodon*), in which the top of the head was as much as 14 ft. from the ground when the ordinary bipedal position was assumed (fig. 335). Of armoured types the most extraordinary (*Triceratops*) was a three-horned animal about as large as a rhinoceros (fig. 336).

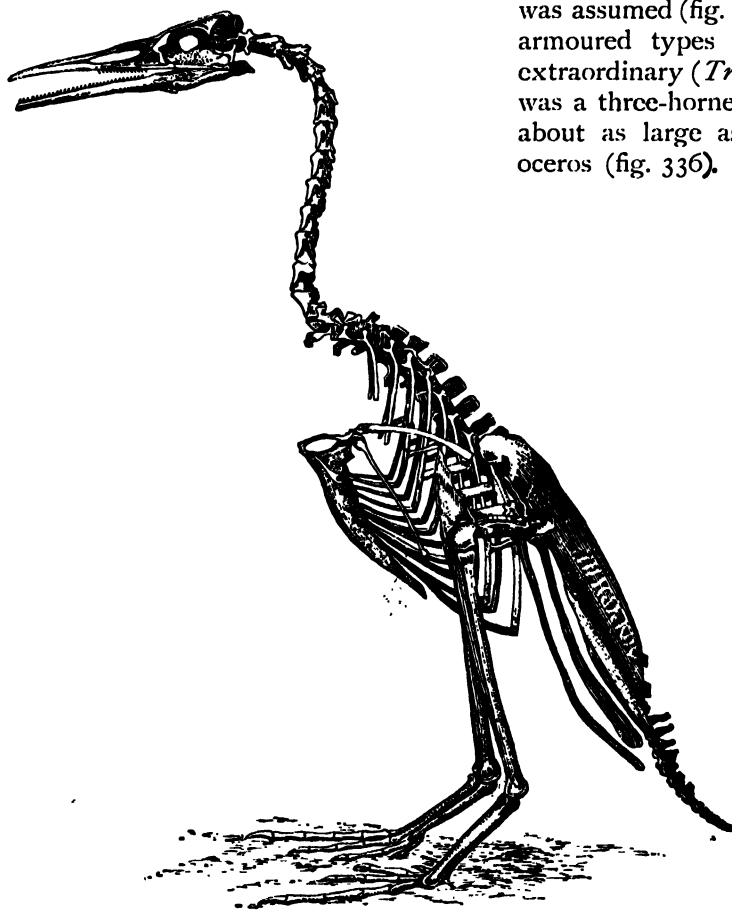


Fig. 338.—*Hesperornis*. (After Marsh.)

We also find the last FLYING REPTILES (ORNITHOSAURS). One toothless American type (*Pteranodon*) was of gigantic size, its spread of wing being about 18 ft. (fig. 337). These remarkable groups of Mesozoic Reptiles seemed unable to compete with the warm-blooded Birds and Mammals, and the small size of their brains seems to have had much to do with their want of success. Speaking of one group, Sir E. Ray Lankester says:—

“A curious fact about these great Dinosaurs is that they had, as compared with big living reptiles such as the crocodiles, very tiny brains. . . . In some the head itself was ridiculously small according to our notions of customary proportion, and even in others, such as Triceratops, where the bony and muscular parts of the head were big, as in the rhinoceros, yet the brain was incredibly small. It could have been passed all along the spinal canal in which the spinal cord lies, and was in proportion to bulk of body a tenth the size of that of a crocodile. Very probably this small size of the brain of great extinct animals has to do with the fact of their ceasing

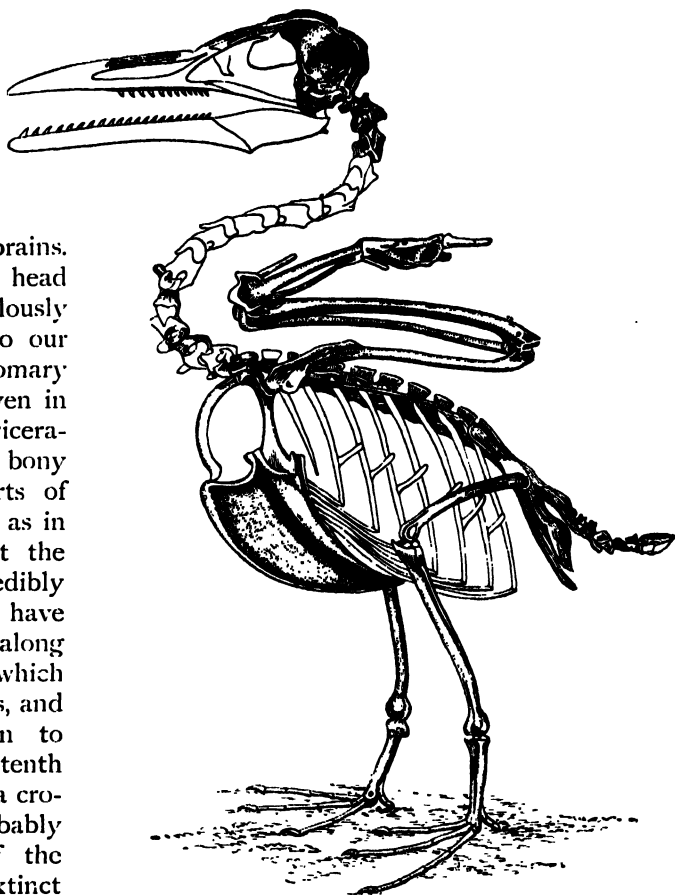


Fig. 339.—*Ichthyornis*. (After Marsh.)

to exist. Animals with bigger and ever-increasing brains outdid them in the struggle for existence” (*Extinct Animals*, pp. 208–9).

BIRDS are scantily represented in the Cretaceous strata, but some extremely interesting American forms are known. One of these (*Hesperornis*) belonged to the same order as existing RUNNING BIRDS (RATITÆ). It was a large diver, about 3 ft. high when standing, with greatly reduced wings, and swimming feet (fig. 338). Both jaws were provided with conical teeth, situated in grooves, but the front part of the upper jaw was sheathed with horn. Another type (*Ichthyornis*), about the size of a pigeon, clearly belonged to the FLYING BIRDS (CARINATÆ) (fig. 339). The wings were

well developed, and the jaws resembled those of *Hesperornis*, except that the teeth were implanted in sockets.

A few imperfect remains of lower MAMMALS, Prototheria and Metatheria (Marsupials), have been found in Upper Cretaceous strata. In America (Wyoming) the Marsupials include Opossums (*Didelphops*).

CHAPTER X

THE EVOLUTION OF ANIMALS IN GEOLOGICAL TIMES—KAINOZOIC EPOCH AND RECENT PERIOD

The Kainozoic epoch, the strata of which grade insensibly into recent or modern deposits, represents a much smaller length of time than the Mesozoic, which in its turn was vastly briefer than the Palæozoic. Most

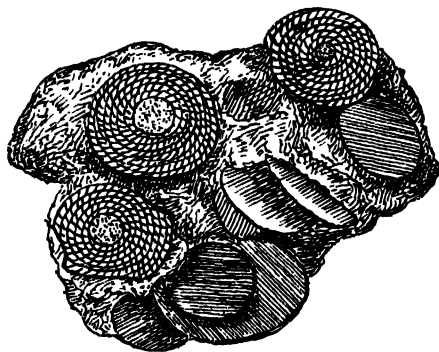


Fig 340.—Nummulites

of the types now dominant were equally so in the early part of the epoch, though since then great changes in detail have taken place, and we are able to trace the gradual evolution of numerous orders, especially those belonging to the higher classes. From the beginning of Kainozoic times the sea has been ruled by highly organized forms, such as cuttle-fishes, bony fishes, and aquatic mammals, while the sovereignty of the land has fallen to birds and terrestrial mammals. It

may be added that the highest flowering plants, with seeds enclosed in special cases (ANGIOSPERMS), have wrested the supremacy from cycads and cone-bearers (GYMNOSPERMS).

The successive stages of the Kainozoic epoch are known as Eocene, Oligocene, Miocene, Pliocene, and Pleistocene. Space prevents more than a brief treatment of the succession of different forms of life, and most of this chapter will be devoted to a consideration of the rise of some of the more important orders of mammals.

MARINE FAUNA.—Although a great many of the FORAMINIFERA are identified with or very similar to Mesozoic types, the group here reached its maximum development, and important Kainozoic limestones are consolidated foraminiferal muds. The members of one family in particular (*Miliolidae*) build up thick Eocene limestones, and remain dominant to recent time. The relatively large coin-shaped Nummulites (*Nummulinidae*) make up the still more important nummulitic limestone of the Eocene and Oligocene periods, afterwards declining in importance, while the members of a third family (*Globigerinidae*) become extremely important from Miocene times onwards (fig. 340).

RADIOLARIA are also locally important as rock builders in Miocene and Pliocene strata. SPONGES present no very remarkable features, but modern types are found here and there throughout the Kainozoic deposits. Corals belonging to the HYDROZOA (*Millepora* and *Stylaster*) exist in increasing numbers in these deposits, and during the recent period play an important part in building up coral reefs. SIX-RAYED CORALS (HEXACOROLLA) of Eocene and Oligocene age made up reefs in what are now the Alpine and Pyrenean areas, but in subsequent periods such reefs were restricted to lower latitudes.

SEA-LILIES (CRINOIDS) became of increasing rarity, and are now limited to the deep sea, but the related FEATHER-STARS have flourished exceedingly, and are widely distributed in the shallowest parts of existing oceans. Both BRITTLE-STARS (OPHIUROIDS) and ordinary STARFISHES (ASTEROIDS) are dominant groups, while among SEA-URCHINS (ECHINOIDS) the irregular types become of increasing importance. MOSS-POLYPTES (POLYZOA) are common, and at some horizons and localities astonishingly abundant, but LAMP-SHELLS (BRACHIOPODS) occupy a very subordinate place in the marine fauna from the beginning of the Kainozoic epoch to the present day. Marine CRUSTACEA, broadly speaking, are of much the same general characters throughout the Kainozoic epoch.



Fig. 341.—*Dreissensia*

Even in Eocene times the BIVALVE MOLLUSCS were very similar to those now existing. A number of new families made their first appearance, among which may be mentioned those typified by the common sand-gaper (*Mya*), and other well-known forms (e.g. *Tridacna*). Carnivorous SEA-SNAILS (GASTROPODS) also included some new types, e.g. the harp-shells (*Harpidae*). Of lower forms, the ormers or sea-ears (*Haliotidae*) first occurred, and we also find the earliest known representatives of certain highly specialized snails (*Heteropods*) with reduced shell and a swimming foot.

Existing sea areas are divisible into a number of "provinces", distinguished by the character of their Gastropods and other Molluscs. In Eocene times some of these provinces began to be broadly sketched out, especially in the Southern Hemisphere, for the Eocene Molluscs of Australia, New Zealand, and South America were clearly ancestral to those now living in the South Atlantic and South Pacific.

The Kainozoic Molluscs also help us to trace the mutations of climate that have taken place in the Northern Hemisphere during that epoch. In our own latitude, for instance, the climate of the Eocene, Oligocene, and Miocene periods was tropical or subtropical. During the succeeding Pliocene and Pleistocene a gradual lowering of temperature took place, culminating in the Great Ice Age. This slowly passed away, to be followed by the more temperate conditions that we still enjoy. It follows that the older Kainozoic Molluscs of Britain find their closest allies some distance to the south, while many of those from the Pliocene and Pleistocene are now represented farther north.

If we except the few reduced survivors of the belemnites, the scanty

remains of which locally occur in the lowest Eocene strata, CEPHALOPODS were mainly represented by cuttle-fishes and a few remnants of the persistent nautilus group.

Among FISHES the specialized "Teleostei" became increasingly dominant from the Eocene period down to the present day. Important new types made their first appearance, *e.g.* cod-like fishes (*Nemopteryx*), pipe-fishes



Fig. 342.—Manatee. (After Muric.)

and sea-horses (*Calamostoma*) in the Eocene; flat-fishes (*Solea*) in the Miocene.

The marine REPTILES of the Mesozoic had all become extinct, but sea-snakes (*Palaeophis*) date from the Eocene, and seem to have attained a length of some 18 ft. Another genus (*Pterospheus*) of marine snakes is represented in the Eocene of Egypt and Alabama, U.S.A. The sea became dominated by Mammals, *i.e.* (1) Sea-cows (Sirenia); (2) Seals and Sea-lions (Pinnipedia); and (3) Whales and Porpoises (Cetacea).

SEA-COWS (SIRENIA) are represented at the present day by the Manatees (*Manatus*) of the tropical Atlantic (fig. 342) and the Dugongs (*Halicornes*) of the Indian and South Pacific oceans. They are herbivorous, estuarine and shallow-water forms, devoid of hind-limbs, and possessing

flipper-like fore limbs. The tail is broadened into a horizontal fin. Our knowledge of the evolution of the group is very imperfect, but they are undoubtedly descended from land mammals, probably hoofed forms (Ungulates). In existing types the hind-limbs are only represented by small bony rods found on dissection, and the teeth are greatly modified for the purpose of chewing vegetable food. Sirenians date from the Eocene, and as we go back in time it is interesting to note that the teeth become more normal, and the vestiges of the hind limbs larger. This is most markedly the case in two genera (*Eotherium* and *Eosiren*) from the Egyptian Eocene.

SEALS and SEA-LIONS (PINNIPEDS) are Carnivores modified for an aquatic life. The limbs are paddles, and the numerous sharply pointed teeth are well adapted to catch fish. The primitive ancestral Carnivores (CREODONTS), which range from Eocene to Miocene, afford a possible clue to the origin of seals and their allies, for an aquatic Eocene type (*Patriofelis*) has been discovered in the lacustrine Middle Eocene strata of Wyoming, U.S.A. Its limbs were short broad paddles, and it seems to

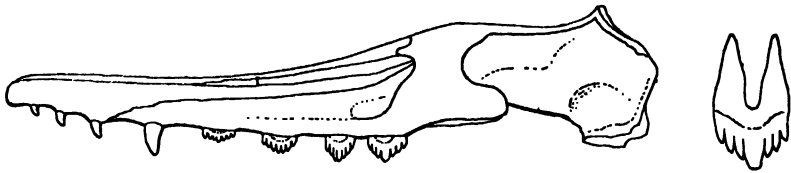


Fig. 343.—*Zeuglodon*, and tooth of same.

have preyed on the freshwater tortoises that swarmed in a lake (the "Bridger Lake") that then existed in that part of North America. Reasoning from the characters of *Patriofelis*, Smith Woodward says: "It is quite possible that the early Tertiary [*i.e.* Kainozoic] ancestors of the Pinnipedia were lake-dwelling animals which eventually wandered into the sea". Undoubted Pinnipeds are first found in Pliocene strata.

WHALES AND PORPOISES (CETACEA).—These are the most specialized of all aquatic Mammals, and have descended from land Carnivores. Some of them are the largest members of their class, bigger indeed than any other known animals. It is no wonder that marine Reptiles have had to give way before them. The body is fish-shaped, the fore-limbs are powerful flippers, and the tail is broadened into a strong horizontal fin, while the hind limbs have dwindled to minute internal vestiges. The hairy covering of the body has been suppressed, warmth being secured by a thick layer of fat (blubber) under the skin. The nostrils are represented by one or two openings (spiracles) on the top of the head, while the windpipe is drawn out into a cone that fits into the back of the nasal passages (cp. Crocodiles, p. 144). There is thus no interference between breathing and swallowing, and no danger of water getting into the lungs.

The oldest known whales (*Protocetus*, *Eocetus*, *Prozeuglodon*, *Zeuglodon*) have been found in Eocene strata, and their teeth (fig. 343) were less modified than those of more modern types. This is particularly true for the Egyptian *Protocetus*, which links whales with the primitive Carnivores

(Creodonts). Such forms no doubt existed in Mesozoic times, though their remains have not yet been discovered.

Toothed whales related to the existing sperm-whales and porpoises made their first known appearance in the Miocene period. Their teeth are numerous and conical. Toothless whales also existed during the same period. Here the teeth are replaced by fringed plates of "whalebone" (baleen) hanging from the roof of the mouth (fig. 344). This is an adaptation to catching and straining out the vast shoals of small animals that make up so large a part of the floating population of the sea (*plankton*).

FRESHWATER AND ESTUARINE FAUNA.—Representatives of various orders of CRUSTACEA occur here and there in the Kainozoic strata, but they present no points of general interest. INSECTS adapted to an aquatic life, either as larvæ or when adult, become more and more common. Among the former are may-flies, dragon-flies, and various two-winged flies (Diptera), while the latter include water-beetles and water-bugs.

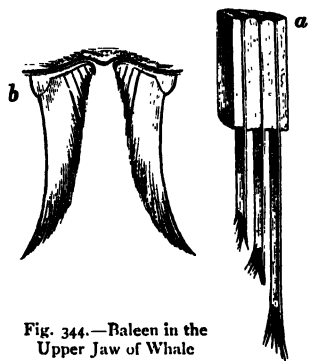


Fig. 344.—Baleen in the Upper Jaw of Whale

a, Section of a portion of the palate of a whalebone whale, showing three baleen plates. *b*, The arrangement of the baleen plates on opposite sides of the jaw.

BIVALVE MOLLUSCS (LAMELLIBRANCHIA) are common, and include not only freshwater mussels, &c., already existing in Mesozoic times, but also new types. One of these (*Dreissensia*), ranging from the Eocene period onwards, is common in our canals to-day, and resembles an edible mussel in appearance (fig. 341). It is interesting because the life-history, as well as the geological history, indicates comparatively recent adaptation to freshwater conditions. Freshwater (and estuarine) GASTROPODS attained a great development, and included

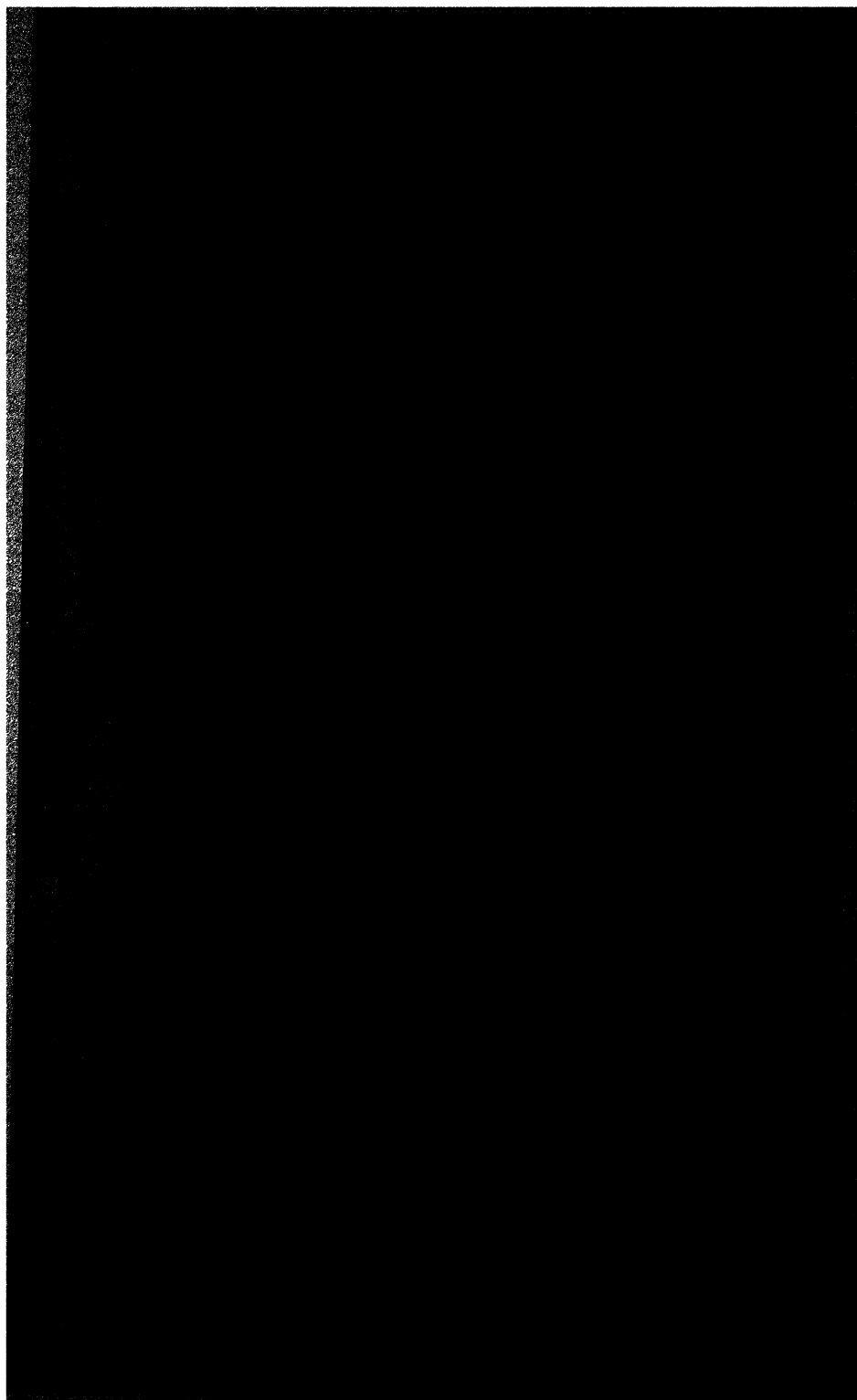
types (*Ancylus*, *Succinea*) of new families. As among marine Gastropods (cp. p. 173), we find evidences of mutations of climate.

With the progress of Kainozoic time the freshwater FISHES became increasingly like those now living. Fringe-finned forms are represented in the Eocene of the Fayûm (Egypt) by forms related to the existing Bichîr (*Polypterus*) of the Nile. Among Ganoid types we find, from the Eocene onwards, the Sturgeons beginning to take the place in the freshwater (and estuarine) fauna of the Northern Hemisphere that they now occupy, while the Bow-fin (*Amia*) and Bony Pike (*Lepidosteus*), now restricted to North America, existed in Europe from the Eocene period until the older Miocene. We also notice the first appearances of certain familiar Teleosts, such as carp (Oligocene), cat-fishes (Eocene), modern eels (Miocene), and pike (Miocene).

REPTILES include freshwater tortoises, one genus (*Chelydra*), now limited to Europe, being also European during the Miocene period. Mud-turtles (*Trinix*) date from the Eocene. Crocodiles and Alligators of specialized type are common in Kainozoic deposits both in North America and Europe, existing into Pliocene times in the latter area. One Pliocene

THE COMMON MACKEREL (*Scomber vulgaris*)

This well-known fish inhabits the Atlantic and Mediterranean, and approaches our shores in large shoals in pursuit of herring. It is remarkable for beautiful coloration, and also for its graceful shape, which is an adaptation to rapid swimming, offering but little resistance to the surrounding water. The symmetrical, deeply-forked tail serves as a propeller of unusual power, and the lateral muscles are of a reddish colour, owing to the abundant blood-supply, which is associated with the power of prolonged and swift movement. The upper and lower rows of "faints" on the hinder part of the body are characteristic.



Indian form (*Rhamphosuchus*) exceeded all other known crocodilians in size, for it was over 48 ft. in length.

As to freshwater MAMMALS see p. 175.

LAND FAUNA.— This vast subject must of necessity be treated very briefly, and Mammals will be considered more fully than other groups, for they are of most interest, and there are abundant materials for sketching the main directions of evolution.

SCORPIONS, SPIDERS, and their allies (ARACHNIDS) are abundant enough from Oligocene times onwards. The deposits of that period are particularly rich in their remains. MITES and TICKS, particularly common as parasites in warm-blooded Vertebrates, here made their first appearance.

CENTIPEDES and MILLIPEDES (MYRIAPODS) occur here and there in Kainozoic strata, but are uncommon.

INSECTS of all orders are represented from the Eocene period onwards, their remains being increasingly abundant in newer strata. MOTHS

and BUTTERFLIES (LEPIDOPTERA) make their first appearance.

These insects are profoundly specialized in relation to their habit of feeding on the pollen and nectar of flowers. This is correlated, of course, with the dominance

of ordinary FLOWERING PLANTS (ANGIOSPERMS), the leading group of land plants during the Kainozoic epoch.

LAND-SNAILS (GASTROPODS) are extremely abundant, including genera representing new families both of snails (*Helix*, *Pupa*) and land-slugs (*Testacella*, *Limax*).

AMPHIBIA are scantily represented in the Kainozoic rocks from the Eocene onwards, both by tailed forms (newts and salamanders) and tail-less genera (frogs and toads).

REPTILES of existing type are here and there found in Kainozoic strata, but Dinosaurs and Ornithosaurs have entirely disappeared. Land Tortoises made their first appearance in the Eocene. Lizards are scarce, but present one or two interesting features. In the earlier part of the epoch some genera (*Iguana*), now limited to America, also existed in Europe. We further find an illustration of a very general rule, that, in many areas, existing land-forms were preceded during Pleistocene times by much larger types of the same kind. In Queensland, for instance, the remains of a lizard (*Megalanina*) over 30 ft. long have been discovered in deposits of this age.



Fig. 345.—Kiwi (*Apteryx*)

Land Snakes are first known from Eocene strata. A python-like form (*Gigantophis*) about 30 ft. long has been found in Egyptian rocks of that period.

None of the Kainozoic BIRDS possessed teeth, and more or less modern types have been found in Eocene strata. The material is too imperfect to render possible any detailed working out of the ancestry of existing families. Many of the older species, however, were undoubtedly "generalized" or "synthetic" types representing stocks from which recent groups have diverged. RUNNING BIRDS (RATITES), *i.e.* ostriches and their allies, are now practically limited to the Southern Hemisphere, but during the earlier part of the Kainozoic epoch existed in the northern land-masses of both hemispheres. Eocene fossils of the kind have been found in West Europe (*Gastornis*, *Dasornis*) and North America (*Diatryma*). The common ostrich (*Struthio*), now restricted to Africa and Arabia, was represented during Pliocene times by closely related forms living in India and the area now occupied by the islands of the Aegean Sea.

During the Pleistocene period, and surviving into comparatively recent times, we find that running birds of diversified kind, and often of great size, existed in the Southern Hemisphere. In New

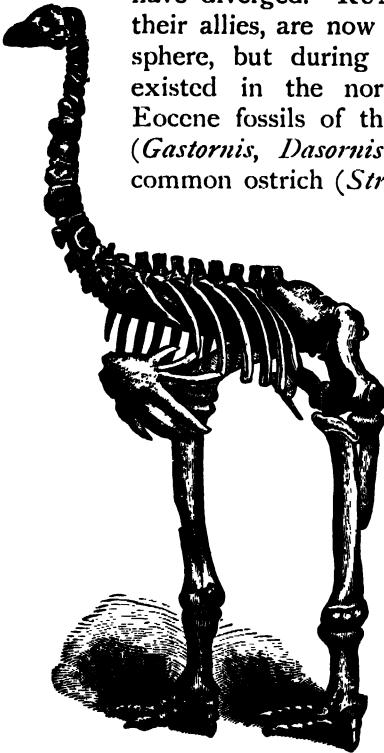


Fig. 346.—Skeleton of Moa (*Pachyornis elephantopus*), much reduced

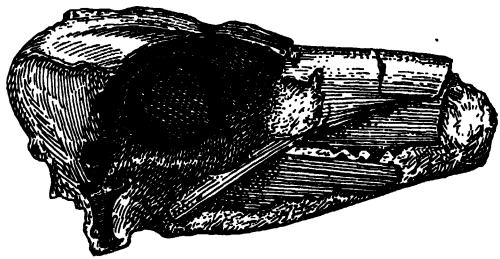


Fig. 347.—Skull of Odontopteryx. Most of the beak is missing, but its base is seen on the right.

Zealand at the present time only one running bird is indigenous, the Kiwi (*Apteryx*), which is not much larger than a hen (fig. 345). But until a few hundred years ago immensely larger forms belonging to the same group existed in that part of the world, and were undoubtedly hunted down and exterminated by the ancestors of the Maoris. These were the Moas, of which the largest (*Dinornis maximus*) attained a height of some 10 ft. (cp. fig. 346). A bird of similar dimensions (*Apyornis maximus*) lived somewhere about the same time in Madagascar, and the huge eggs of this species no doubt originated the fables about the famous "roc", with which all are familiar in the stories of Aladdin and Sindbad the Sailor narrated in *The Arabian Nights*.

The FLYING BIRDS (CARINATES) need not detain us. A curious fish-

eating form (*Odontopteryx toliapica*), probably related to the gannets, is found in the English Eocene. It is remarkable for the tooth-shaped indentations on the edges of the beak (fig. 347). Patagonian Kainozoic strata have yielded the remains of a gigantic bird of prey (*Phororhachos*), apparently related to the existing Cariamas or Screamers (fig. 348). Of this Sir E. Ray Lankester says: "If the extinct bird had the general proportions and habits of the *Cariama*, as seems probable, it must have been a terrible monster, standing some 12 ft. high, and far exceeding the most powerful eagles and vultures in strength and the size of its beak and claws".

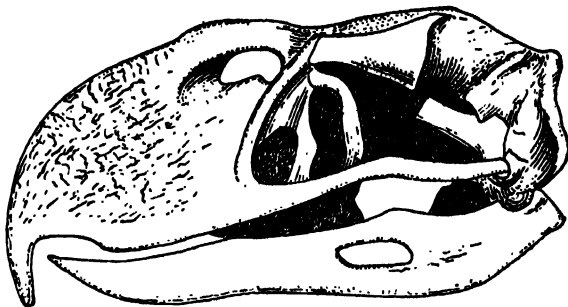


Fig. 348.—Skull of *Phororhachos*

CHAPTER XI

THE EVOLUTION OF ANIMALS IN GEOLOGICAL TIME—KAINOZOIC EPOCH AND RECENT PERIOD (Continued)

KAINOZOIC LAND MAMMALS.—The Kainozoic epoch witnessed the rise of land mammals to the dominant place in the terrestrial fauna occupied by reptiles during Mesozoic times. The earlier stages in mammalian evolution appear to have taken place in a southern land-mass which has now largely disappeared, and the fossils available for reconstruction of these early stages are too scanty to be of much use. Smith Woodward says: "It is . . . still impossible to trace the evolution upwards to the base of the Cainozoic or Tertiary strata, in which typical and well-preserved mammalian skeletons occur in abundance. The only mammalian fossils hitherto discovered in the Jurassic and Cretaceous rocks are merely fragments of a most unsatisfactory nature. They represent tribes of dwarfed animals not larger than rats, some probably related to the existing monotremes, others to the marsupials, more clearly belonging to the highest mammalian type (that of the Eutheria), or linking this with the grades below" (*Vertebrate Palaeontology*, p. 247).

As elsewhere stated, Mammals are divided into three sub-classes: (1) Prototheria; (2) Metatheria; and (3) Eutheria; which will be considered in succession.

PROTOTHERIAN MAMMALS

These include two orders, Multituberculates and Monotremes.

MULTITUBERCULATES.—To this order are referred some of the Mesozoic remains to which allusion has already been made (see p. 162). The available material consists almost entirely of detached lower jaws, and the presence of numerous small tubercles on the crowns of the grinding teeth gives the name to the order. Some of the oldest fossils cannot be distinguished with certainty from those belonging to certain Permian and

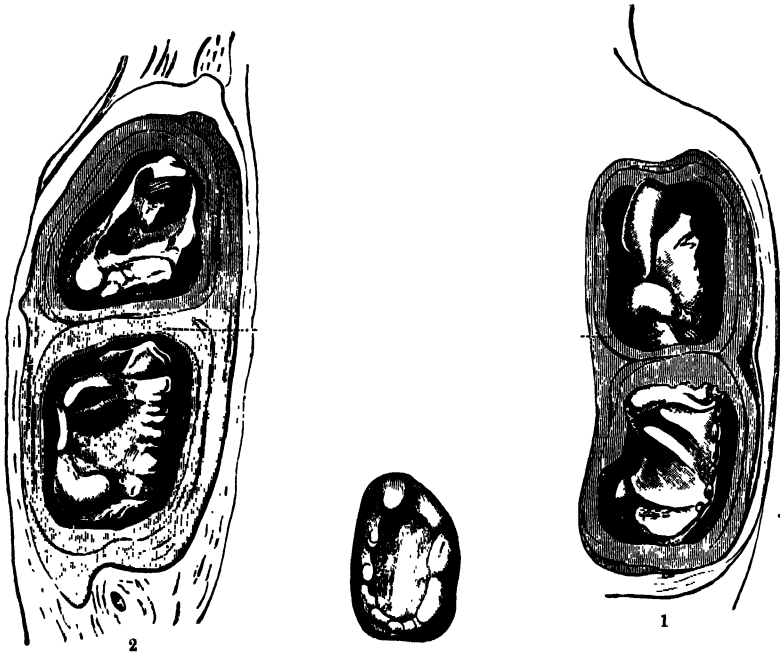


Fig. 349.—1 and 2, Upper and lower grinding teeth of a young Duck-mole (*Ornithorhynchus*, natural size and enlarged. 3, Grinding tooth (enlarged) of an extinct Mesozoic mammal (*Microlestes*).

Triassic reptiles (see p. 143), and this suggests the ancestry of mammals; while, on the other hand, a resemblance to the transient grinding teeth of the Duck-mole (*Ornithorhynchus*) justifies their association with the members of the next order.

MONOTREMES.—Two existing Australian types belong to this order, *i.e.* the Duck-mole (*Ornithorhynchus*) and the Spiny Ant-eaters (*Echidna* and *Proechidna*). They are small, burrowing, egg-laying mammals, devoid of teeth when adult. The Duck-mole is aquatic, and feeds largely on water-snails, which are crushed by horny plates that supplant minute tuberculate molars (fig. 349). Some of the late Kainozoic deposits of Australia contain the remains of very much larger animals of the kind.

POUGHED MAMMALS (Marsupials)

1. Tree-Kangaroo of New Guinea (*Dendrolagus inustus*).
2. Koala (*Phascolarctos cinereus*).
3. Water Opossum (*Chironectes minimus*).
4. Pig-footed Bandicoot (*Charopus castaneotis*).
5. Tasmanian Devil (*Sarcophilus harrisii*).
6. Squirrel-like Flying Phalanger (*Petaurus sciuroides*).
7. Jerboa Pouched-mouse (*Antechinus laniger*).
8. Philander Opossum (*Didelphys philander*).
9. Great Grey Kangaroo (*Macropus giganteus*).
10. Tasmanian Wolf (*Thylacinus cynocephalus*).
11. Hairy-nosed Wombat (*Phascogaleus latifrons*).
12. Gunn's Bandicoot (*Perameles gunni*).
13. Common Dasyure (*Dasyurus viverrinus*).

Numbers 9 and 10 are American species, the remainder being of the Australian region.



GROUP OF POUCHED MAMMALS (MARSUPIALS)

NUMBERS 1 AND 2 ARE ADULTS, AND 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 ARE JUVENILES.

METATHERIAN MAMMALS

These are represented by somewhat higher types than those included in the last sub-class, all of them belonging to the single order of MARSUPIALS (Pouched Mammals), so called because the young, born in a very helpless condition, are sheltered in a pouch present on the under side of the mother's body. The vast majority of existing Marsupials (kangaroos, wombats, phalangers, &c.) are limited to the Australian region, but the opossums range through both Americas, and one small rat-like form (*Cænolestes*) is indigenous to South America.

Allusion has already been made (see p. 151) to the primitive nature of the Australian fauna, and, so far as terrestrial animals are concerned, this



Fig. 350.—Skull of the Giant Australian Marsupial (*Diprotodon*) preserved in the British Museum (Natural History). By its side a human skull is drawn to the same scale. (From Sir E. Ray Lankester.)

appears to be due to a comparatively early separation from the northern land-mass of the Old World, whereby the entry of highly specialized types was prevented.

Marsupials are divided into the two sub-orders of Polyprotodonts and Diprotodonts, the former being less specialized than the latter.

POLYPROTODONT MARSUPIALS.—These are distinguished by the possession of several front teeth (incisors) in the lower jaw. Eye-teeth (canines) are also present. Some of the Mesozoic mammals (see p. 162) are placed here, and so are the opossums, ant-eating bandicoots (*Perameles*), and Tasmanian “native wolf” (*Thylacinus*). From Eocene to Miocene times opossums existed in Europe as well as America, while the remains of thylacines have been discovered in the Patagonian Miocene.

DIPROTODONT MARSUPIALS.—In these forms there are no canine teeth, and only a single large pair of lower incisors. Practically all existing types are restricted to the Australian region. The little *Cænolestes* of South America belongs to a group more numerous represented on that continent during Miocene times. A couple of Pleistocene Australian forms deserve mention. One of these (*Diprotodon*), the largest known Marsupial,

was a herbivorous creature about the size of a rhinoceros (fig. 350). The other, known as the "pouched lion" (*Thylacoleo*), was about a quarter that size. It is by no means certain that it was carnivorous, as the name implies.

EUTHERIAN MAMMALS

These include the most specialized members of their class. Compared with Marsupials they are born in a well-developed state, this being rendered possible by a complex structure (*placenta*) that places the blood-vessels of the embryo in close relation with those of the mother. Hence Eutherians are often known as "placental" Mammals, though a feebly developed placenta is not unknown among Marsupials (*Peramelis*).

EUTHERIAN ORDERS.—The sub-class is divided into no less than nine orders, as follows:—

1. Whales and Porpoises (Cetaceans);
2. Sea-cows (Sirenians);
3. Mammals poor in teeth (Edentates);
4. Hoofed Mammals (Ungulates): swine, cattle, horses, elephants, &c.;
5. Gnawing Mammals (Rodents): rabbits, rats, squirrels, porcupines;
6. Flesh-eaters (Carnivores): cats, dogs, bears;
7. Insect-eating Mammals (Insectivores): hedgehogs, shrews, moles;
8. Bats (Chiroptera); and
9. Lemurs, Monkeys, and Man (Primates).

The aquatic orders (1, 2, and 6 in part) have already received treatment (see pp. 174-6). All the orders are represented from Eocene times onwards.

MAMMALS POOR IN TEETH (Edentates).—These apparently degenerate forms seem to have been derived from an ancestral stock that also gave rise to hoofed and gnawing mammals. They exist at present in the southern parts of the great land-masses, being represented by the sloths, ant-eaters, and armadillos of South America, the Cape Ant-eater (*Orycteropus*) of South Africa, and the scaly ant-eaters or pangolins (*Manis*) of Africa and Southern Asia.

The existing South American Edentates are comparatively small and unimportant, for they have had to compete with more highly organized mammals, which have now gained the upper hand. But during late geological times South America was not united with her sister continent in the north, and the dominant mammals were Edentates, some of these being of large size.

The small leaf-eating Sloths, that live in trees, suspended upside down by their hook-like claws, were then represented by great Ground-sloths (*Megatheriidae*), which also resembled in some respects the modern Ant-eaters. The largest of these (*Megatherium*) was about the size of an elephant, and it appears to have been in the habit of pulling down trees for the sake of their foliage. Another somewhat similar form (*Myodon*, fig. 351) was of similar habit, but differed in the fact that small nodules of bone were embedded in its skin. A closely allied if not identical animal (*Neomyodon*) existed in quite recent times, geologically speaking, and possibly still survives, though this is highly improbable.

AN EXTINCT GROUND-SLOTH (*Megatherium*)

It is a remarkable fact that certain groups of land-animals were in part represented, in comparatively late geological times, by gigantic forms which have since become extinct. This is the case, for example, with the Mammals poor in Teeth (*Edentata*), to which belongs the South American Ground-Sloth (*Megatherium*) represented in the plate, which is taken from a photograph of a restoration in the British Museum. In size it was nearly as large as an elephant, and is believed to have fed on leaves, as do the relatively insignificant Sloths which now live in the trees of the South American forests. The plate represents the Ground-Sloth in the position it assumed for the purpose of pulling down branches, or uprooting small trees, in order to obtain its food.



EXTINCT SOUTH AMERICAN GROUND-SLOTH (MEGATHERIUM)

The bones, skin, and dung of this creature have been found, in a comparatively fresh state, in the cave of Ultima Speranza, South Patagonia. It is certain that the cave was once inhabited by Indians, who used this extraordinary Edentate as food, and perhaps kept it in captivity.

Not only sloths but also Armadillos were represented in South America during Pleistocene times by relatively large forms. Of these the Giant Armadillo (*Glyptodon*, fig. 352) attained a length of from 12 to 16 ft.



Fig. 351.—The skeleton of *Mylodon robustus*, one of the giant Ground-sloths of the Argentine, about as big as a large bull. Above it is placed (natural position reversed) the skeleton of a recent Tree-sloth for comparison. Both skeletons are reduced to the same scale. (From Sir E. Ray Lankester.)

Among the causes which led to the extinction of the Pleistocene Edentates of South America must be mentioned the upheaval which caused union with North America, enabling mammals of higher type to migrate southwards. If South America had remained isolated it would now be a second Australia, zoologically speaking.

The Old World Edentates, like those of the New World, are the remains of a primitive mammalian fauna, in this case reduced to still scantier dimensions by the struggle for existence. Very little is known

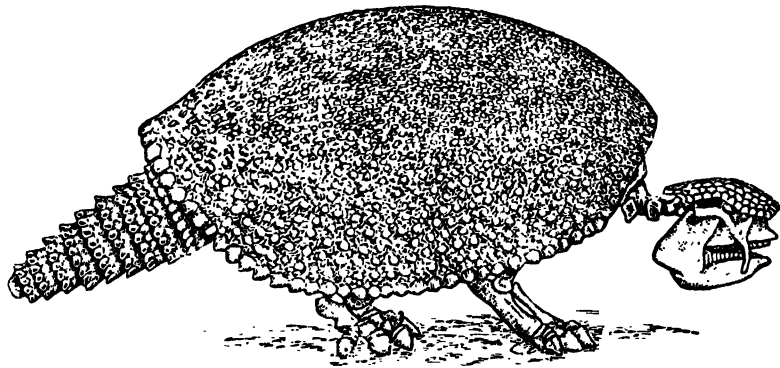


Fig. 352.—Giant Armadillo (*Glyptodon*)

of their geological history, but Pangolins or scaly Ant-eaters seem to have lived in West Europe (France) during the Eocene period. The



Fig. 353.—The Aard-Vark or Cape Ant-Eater (*Orycteropus Capensis*)

burrowing nocturnal Cape Ant-eater or Aard-vark (*Orycteropus*, fig. 353), now restricted to South Africa, existed in South-east Europe and South-

west Asia during Pliocene times, and a closely allied form (*Palæoryctopus*) has been described from the French Eocene.

HOOFED MAMMALS (UNGULATES).—This great group of herbivorous (and in some cases omnivorous) mammals is divided into no less than eleven sub-orders, only four of which are represented by existing species. Their names are as follows, extinct sub-orders being indicated by *italics*:—

(1) *Primitive Ungulates* (*Condylarthra*); (2) Conies (*Hyracoids*); (3) *Blunt-footed Ungulates* (*Amblypods*); (4) *Heavy-footed Ungulates* (*Barypods*); (5) Elephants (*Proboscidea*); (6) *Claw-footed Ungulates* (*Ancylopods*); (7) *Typtotheres*; (8) *Curved-toothed Ungulates* (*Toxodonts*); (9) *Smooth-heeled Ungulates* (*Litopterns*); (10) Odd-toed Ungulates (*Perissodactyles*); (11) Even-toed Ungulates (*Artiodactyles*). (2) and (5) are often elevated to the rank of distinct orders.

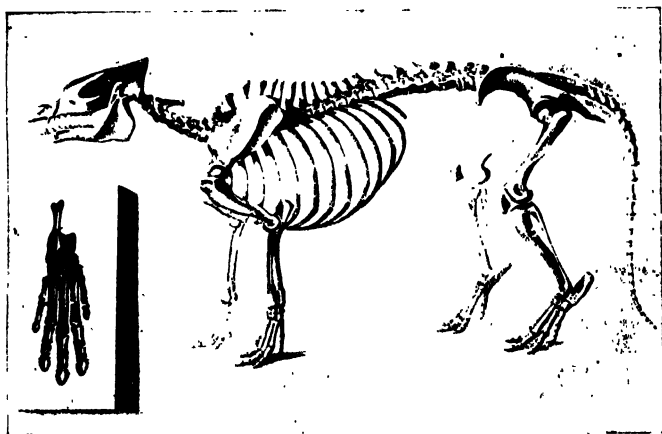


Fig. 354.—Skeleton of *Phenacodus*, a five-toed Eocene animal related to the ancestors of the horse. The inset shows the right hind foot on a larger scale. (From Ray Lankester.)

The course of adaptation in Ungulates is thus ably summarized by Smith Woodward:

“As the course of evolution is traced upwards through the Tertiary formations, the changes in the skeleton are all much of the same type. In general terms, they relate to the modification of small marsh-dwelling or forest-dwelling animals, which were adapted to live on succulent vegetation, into hard-hoofed quadrupeds more fitted for life on grassy plains and with powerful grinding teeth capable of masticating comparatively coarse and dry herbage. The theory is indeed often advanced, that the whole of this development of the Ungulata was correlated with the incoming of grasses as a dominant feature in the earth's flora. Foremost in the advance the brain has become relatively larger and of a higher type.” (*Vertebrate Palæontology*, pp. 287–8.)

PRIMITIVE UNGULATES (CONDYLARTHRA).—In the Lower Eocene strata of Wyoming, U.S.A., have been found the skeletons of mammals about the size of pigs (*Phenacodus*, &c., fig. 354), which if not the actual ancestral stock of Ungulates come very near it. They were adapted to life

on swampy ground, and possess generalized characters from which by suppression and specialization more highly organized types may be supposed to have come into existence.

The head was small, and contained a brain of corresponding dimensions, no doubt correlated with a low intelligence. The teeth were 44 in number, and this may be taken as the full complement for Eutherian Mammals. The dental formula was —

$$i. = \frac{3-3}{3-3}, c. = \frac{1-1}{1-1}, p.m. = \frac{4-4}{4-4}, m. = \frac{3-3}{3-3} = 44$$

(*i.* = incisors; *c.* = canines; *p.m.* = premolars; *m.* = molars). The two last kinds are collectively known as cheek-teeth or grinders. In each fraction the numerator and denominator respectively refer to upper and lower teeth, while the two numbers side by side have reference in either case to teeth on opposite sides of the jaw. The formula can be abbreviated

$$\text{to } \frac{3143}{3143}.$$

The grinders possessed short crowns studded with tubercles, efficient enough for masticating soft marsh plants.

Turning now to the limbs, we find that these were comparatively short and flexible, the latter character being due to the full development of the two bones (radius and ulna) of the forearm, and also (tibia and fibula) of the lower leg, and the fact that the small irregular bones of wrist and ankle did not interlock. These animals were *plantigrade*, *i.e.* they walked on palms and soles, and five digits were present in both hand and foot. The sprawling extremities were well adapted to movement on a soft surface.

CONIES (HYRACOIDS).—These are small animals native to Africa and Syria, and somewhat rabbit-like in appearance. Little is known of their geological history, but they appear to have descended from the primitive mammals of the last sub-order without having undergone much specialization.

BLUNT-FOOTED UNGULATES (AMBLIPODS).—These were large clumsy Eocene mammals, with strong limbs and robust five-toed extremities. The blunt digits were encased in rounded hoofs, and to some extent raised up, presenting a transition to the *digitigrade* condition, where the weight of the body rests on the ends of the toes. The crowns of the grinding teeth were ridged, and the upper canines were large and tusk-like. These creatures probably failed in the struggle for existence because their small smooth brains remained unimproved.

Both European and North American forms are known. One of the latter (*Dinoceras*), not much inferior in size to an elephant, and with three pairs of horns, is represented in fig. 355.

HEAVY-FOOTED UNGULATES (BARYPODS).—This sub-order has been recently constituted for the reception of a massive form—*Arsinoïtherium*—of which remains have been found in the Egyptian Upper Eocene. This creature was nearly 10 ft. long, and stood about 5 ft. 9 in. at the withers.

Its most remarkable feature consists in the possession of four horns, a small posterior and a huge anterior pair (fig. 356). Each of these is



Fig. 355. Probable appearance in life of *Dinoceras mirabile* of North America. (From Sir E. Ray Lankester.)

made up of a bony "core", which was probably covered with a horny sheath. The teeth are 44 in number, and form a continuous graded series.

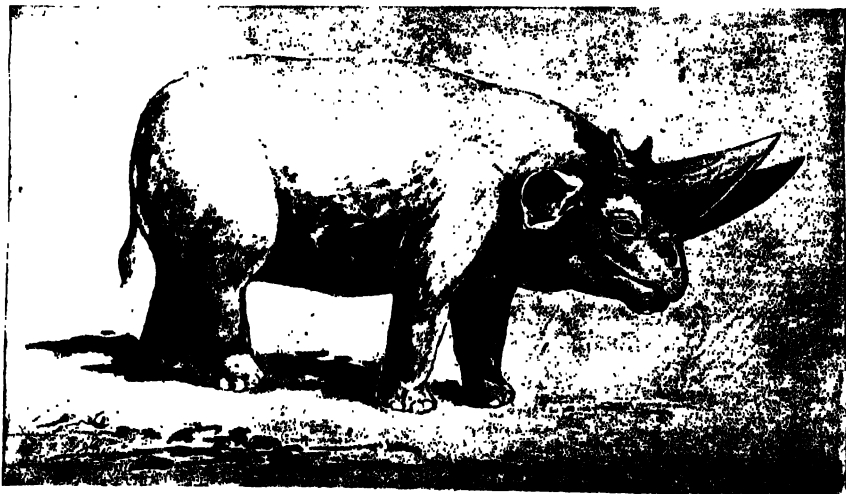


Fig. 356.—Probable appearance in life of *Arasinotherium*. (From Sir E. Ray Lankester.)

The canines are small, one point of difference from the Amblypods. The brain was larger than in the latter. The exact affinities of Barypods

are doubtful, but there are points of resemblance to the three sub-orders already described, and also to the Elephants and their allies which have now to be considered.

ELEPHANTS (PROBOSCIDEA).—Until quite recently the ancestry of Elephants was but imperfectly known. They present a curious mixture of primitive and specialized characters. The former are seen in the structure of the feet and some of the internal organs. The latter are exemplified by the trunk, the tusks (upper incisors), and the huge complex grinders, of which only four are present in the fully adult animal. The discovery of very ancient proboscidean forms in the Eocene strata of the Egyptian Fayûm has, however, solved this very interesting problem.

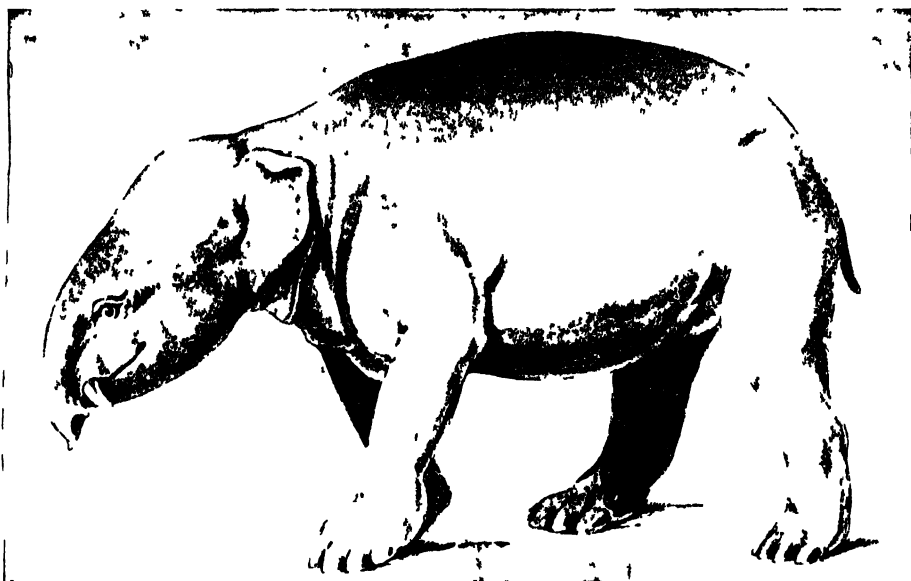


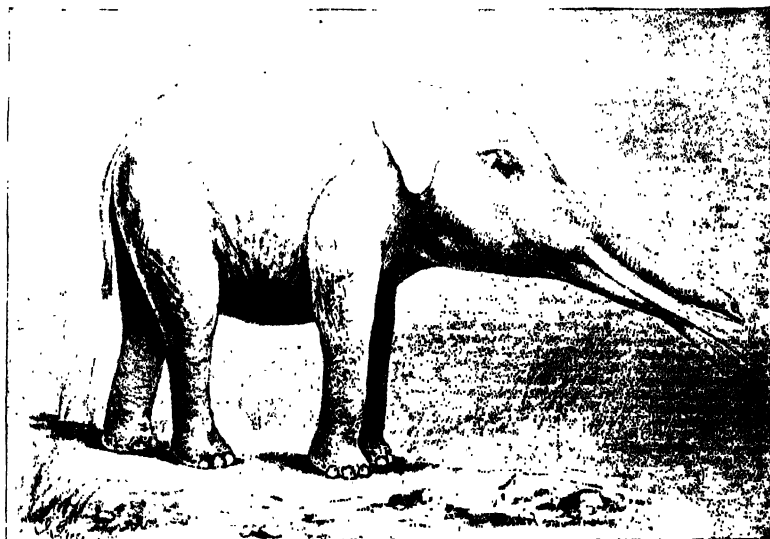
Fig. 357.—Probable appearance in life of *Meritherium*. Drawn by Miss Woodward. The upper lip is probably made too trunk-like. (From Sir E. Ray Lankester.)

The oldest and most primitive of these, *Meritherium* (fig. 357), was about the size of a pony, but much more stoutly built, with a decided resemblance to an elephant. The nose was drawn out into a very short trunk, which is somewhat exaggerated in the restoration figured. We may consider the trunk to be an adaptation to easy grazing in bulky animals with fairly long pillar-like legs. *Meritherium* possessed the full complement of 44 teeth, with transversely ridged crowns to the grinders, small canines, and four of the incisors produced into short tusks, probably to serve as defensive weapons.

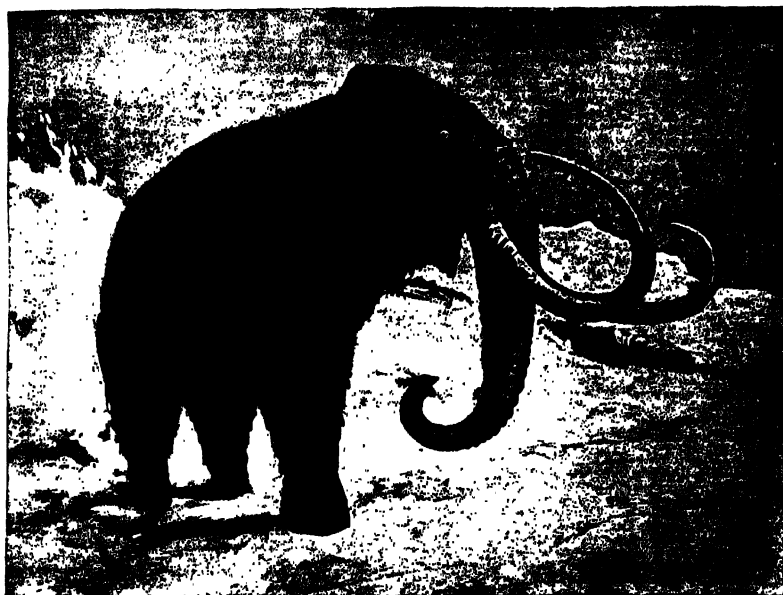
The accompanying figure (358) represents the skulls of *Meritherium*, the Indian Elephant, and intermediate types, *i.e.* *Palæomastodon* (Egyptian Eocene), *Tetrabelodon* (French Miocene), and the *Mastodon* (American Pleistocene). They form a complete series, in which the face became more and more bent downwards, the grinders fewer and more complex, the

ANCESTRAL ELEPHANTS

1. Tetrabelodon, a Miocene elephant with lower as well as upper tusks, and comparatively simple grinders.
2. The Mammoth, a hairy extinct elephant that ranged over the northern land-masses in prehistoric times. It was contemporary with early man in Western Europe and elsewhere, and frozen carcasses are from time to time discovered in Siberia.



1. TETRABELODON



2. MAMMOTH

ANCESTRAL ELEPHANTS

canines suppressed, and only the elongating tusk-like incisors retained. In the last two stages the lower tusks disappeared and the chin was reduced in size. Concomitantly with this the trunk increased in length and complexity, while the size of the body was augmented.

A collateral but entirely extinct branch of the elephant sub-order is represented by *Dinotherium*, the remains of which are found in the Miocene and Pliocene strata of Europe and the Pliocene of India. In many respects they resembled mastodons, but the upper tusks were absent, and the front

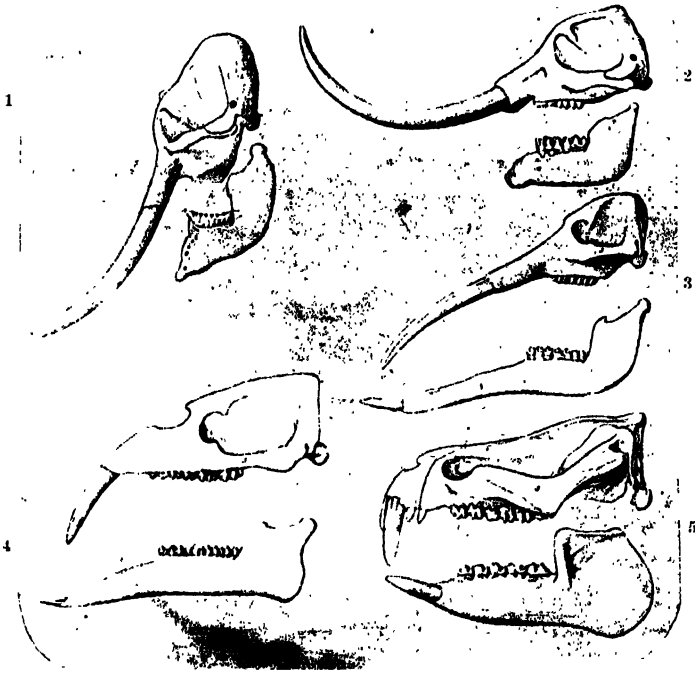


Fig. 358.—Profile views of a series of Elephant ancestors, from drawings by Dr. Andrews

1, Indian Elephant. 2, American Mastodon. 3, Miocene, *Tetrabelodon* (France). 4, Eocene, *Palaeomastodon* (Egypt). 5, Eocene, *Meritherium* (Egypt). (From Sir E. Ray Lankester.)

of the lower jaw was strongly bent. The stout tusks embedded in this were perhaps used for grubbing up water plants from lakes and river beds.

CLAW-FOOTED UNGULATES (ANCYLOPODS).—These were large animals that lived in the Northern Hemisphere during the Miocene and Pliocene periods. Like some of the Edentates, they were supported chiefly on the outer sides of the twisted feet. The toes curved upwards and ended in almost claw-like hoofs.

The members of the next three sub-orders are only known from the Kainozoic strata (Miocene and Pleistocene) of South America, and the following instructive remark is made concerning them in the *Guide to the Fossil Mammals and Birds of the British Museum* (9th ed., 1909, pp. 48–50):

"South America seems to have been separated from the rest of the world during the greater part of the Tertiary period [*i.e.* Kainozoic epoch], and its indigenous hoofed mammals, commonly arranged in three sub-orders, are nearly all different from any found elsewhere. The South American llamas, deer, peccaries, tapirs, extinct horses, and mastodons, of course, are not indigenous, but passed south over the newly emerged Isthmus of Panama or other land bridge at the beginning of the Pliocene period" (cp. p. 182).

TYPOTHERES.—The earliest members of this sub-order closely resembled the primitive Ungulates (Condylarthra) and Amblypods of the Northern



Fig. 359.—Malayan Tapir

Hemisphere, and possessed a full dentition, but as time went on, the canines were suppressed, and the other kinds of teeth reduced in number. Similarities to the gnawers (Rodents) can be traced, of which the most interesting is found in the characters of the incisors. In the oldest types these possessed definite "roots" or "fangs", and were 12 in number. But in the latest form—*Typotherium*—the large incisors were reduced to two above and five below. They did not narrow into fangs, but grew continuously throughout life as in a rat or rabbit, an evident adaptation to gnawing hard vegetable substances.

CURVED-TOOTHED UNGULATES (TOXODONTS).—These closely resembled the members of the last sub-order, but were rather more specialized. The somewhat curved teeth commonly grew continuously, and reduction in number only affected the canines and upper incisors. The most familiar type—*Toxodon*—was about 9 ft. long, and Sir E. Ray Lankester suggests that it looked like a "huge guinea pig".

SMOOTH-HEELLED UNGULATES (LITOPTERNS).—These receive their

name from the presence of a smooth surface on the heel-bone for receiving the end of the small bone of the leg (fibula). They were not unlike horses in appearance, and their toes were gradually reduced in number during the course of evolution, much as was the case in those animals (cp. p. 193). But their teeth never became so specialized, and as their brains remained small they succumbed in the struggle for existence.

ODD-TOED UNGULATES (PERISSODACTYLES).—These include existing tapirs, rhinoceroses, and horses, in all of which there is an odd number of toes on the hind-foot. Beginning with the thumb or great toe, as the case may be, the digits are successively numbered 1, 2, 3, 4, 5, and in the present



Fig. 360.—Indian Rhinoceros

sub-order the middle one (3) became more or less dominant, while some of the others dwindled or even disappeared. This represents adaptation to rapid locomotion on a more or less firm surface. At the same time the limbs elongated and the position became *digitigrade*, i.e. a "tiptoe" attitude was assumed; this also having reference to the conditions of life. There is a strong contrast with the five-toed extremities of the primitive Ungulates, and their mode of walking on palms and soles, i.e. in *plantigrade* fashion, characters suited to swamp or marsh life.

The development of arrangements promoting swift movement had reference not merely to securing of food, but also to escape from the carnivorous mammals evolving side by side with their vegetarian relatives. Nor must we forget that the members of the few surviving sub-orders of Ungulates, and other now dominant mammals, owe their success not only to advance in the direction of mechanical perfection, but also to increasing intelligence associated with a relatively large and complex brain. It will suffice for our present purpose to trace the pedigrees of tapirs, rhinoceroses, and horses.

TAPIRS.—These are the most primitive existing odd-toed Ungulates, somewhat like large pigs in appearance (fig. 359), with an elongated snout.

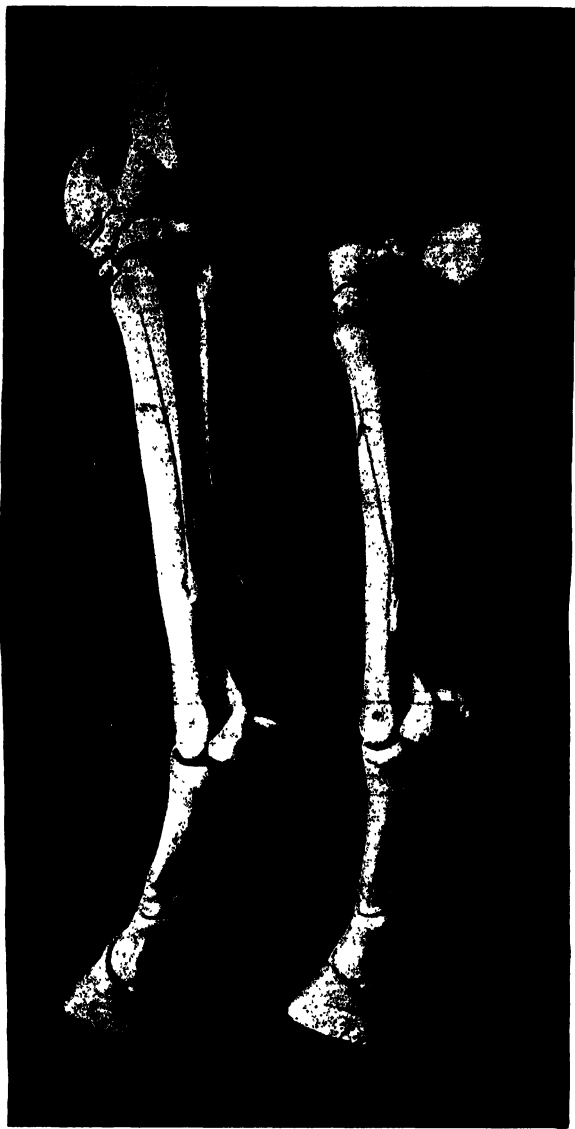


Fig. 361.—Hind and fore foot of an English cart-horse, to show the single toe of three pieces or joints, and the small splint bones beneath the ankle and wrist. (From Sir F. Ray Lankester.)

There are 4 toes on the fore foot and 3 on the hind, digit 1 having disappeared in the former, 1 and 5 in the latter. They present a typical case of "discontinuous" distribution, existing only in the marshes and damp forests of tropical America and the Malay region. It may be laid down as a general principle that animals so distributed are the survivors of an ancient and once widely extended group, which has succumbed to competition with better-adapted forms except here and there. And we know from geological evidence that tapirs ranged over the warmer parts of the Northern Hemisphere during the Miocene and Pliocene periods. Their probable ancestors can be traced back to the Lower Eocene (*Systodon*, &c.).

RHINOCEROSSES.—The existing animals of this kind are also discontinuously distributed, being limited to Africa and South Asia. They are distinguished by their large size, one or two epidermic unpaired

horns, and three-toed extremities (digits 1 and 5 having disappeared) (fig. 360). In Pleistocene times rhinoceroses were widely distributed over the land-mass of the Northern Hemisphere in the Old World, and can be traced back to the Middle Miocene of Europe. Their less-specialized and hornless ancestors date from late Eocene times in Europe and North

America, and very probably derive from still older forms (*Hyrachyus*, &c.) native to the latter continent.

HORSES.—These are in all respects the most specialized Perissodactyles, with very complex elongated grinding teeth and one-toed feet, in which digit 3 alone survives, though traces of 2 and 4 (splint bones) can be found on dissection (fig. 361). At present horses and their allies are indigenous only to Africa and Asia, but in Pleistocene times they ranged through both the Americas. Their ancestry can be traced back to the Lower Eocene (*Hyracotherium*) of Europe and North America (fig. 362). Some of the



Fig. 362.—Probable appearance in life of *Hyracotherium*, an Eocene ancestor of the horse, with four toes on the front foot and three on the hind foot. It was not bigger than a large dog. After a drawing issued by the American Museum, New York. (From Sir F. Ray Lankester.)

evolutionary stages are represented in fig. 363. They involve (*a*) increase in size—the oldest horse-like types were no larger than foxes; (*b*) elongation of the limbs, and reduction of one of the two bones in forearm (*ulna*) and lower leg (*fibula*), in the interests of firmness; (*c*) enlargement of the middle digit and (3) reduction of the others; (*d*) increase in length and complexity of the grinding teeth. Special interest attaches to the ancestry of horses, for it was the first case of the pedigree of an existing animal to be worked out in detail.

EVEN-TOED UNGULATES (ARTIODACTYLES).—Living members of this sub-order are distinguished by an *even* number of toes in the extremities, but here *two* digits (3 and 4) are dominant, and the axis of the limb falls between them. They are subdivided as follows:—

A. NON-RUMINANTS—

Hippopotami, pigs, and peccaries (*Suina*).

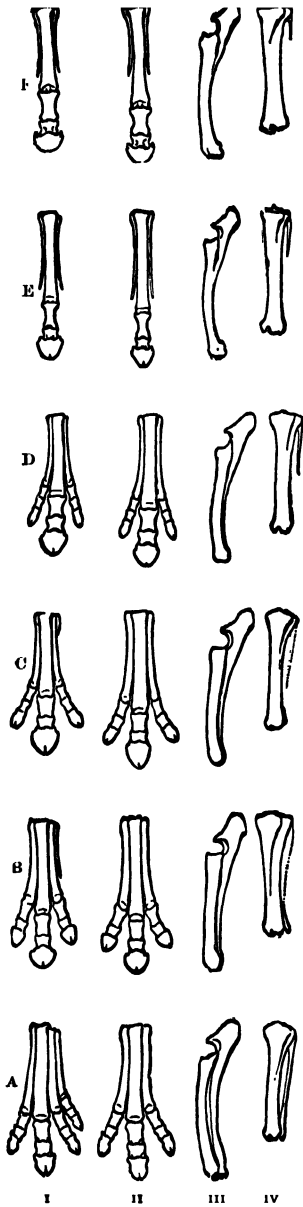


Fig. 363.—Evolution of Limbs of Horse

I, Fore foot; II, hind foot; III, forearm; IV, lower leg. A–F, Bones of extinct horse-like animals, Orohippus, Mesohippus, Miohippus (*Auchitherium*), Protohippus (*Hipparion*), Pliohippus. F, Bones of horse (*Equus*). Read from below upwards (*i.e.* in order of geological age), and note gradual reduction in number of digits, and diminution of size of one forearm bone (*ulna*), and one lower leg bone (*fibula*).

B. RUMINANTS—

Camels and Llamas (TYLOPODS);
Chevrotains (TRAGULINES);
Giraffes, deer, sheep, and cattle (PECORA).

NON-RUMINANTS. — In these relatively primitive forms the grinding teeth are *bunodont*, *i.e.* they possess broad tubercles adapted for crushing succulent plants or other soft kinds of food. The Hippopotamus, a vegetarian form now limited to Africa, remains comparatively unspecialized, but the front teeth are peculiar, and the brain complex. During Pleistocene times, however, hippopotami were widely distributed through Eurasia. Dwarf species existed in Sicily, Malta, Cyprus, and Madagascar. The genus (*Hippopotamus*) to which all the foregoing belonged is first known from the Lower Pliocene of India and Burma.

Pigs are typical Old World forms of omnivorous habit, and can be traced back to the Miocene period in Europe. More ancient pig-like animals date from the Lower Eocene of Europe and North America. Nothing is known about the descent of the peccaries, which are American allies of the pigs.

It should be mentioned before passing to the next group that in all the Non-ruminants the first digit is suppressed. The extremities of a hippopotamus are short and strong, and terminate in four stout toes. Those of a pig are somewhat longer, and the central digits (3 and 4) are much larger than the outer ones (2 and 5). The latter do not touch the ground in walking, but serve as “stops” to hinder the feet from sinking too deeply into soft ground.

RUMINANTS. — The animals of this kind now existing are swiftly moving vegetarian forms with extremities more or less elongated and specialized. The outer digits (2 and 5) are much reduced or practically absent, while the two long palm-bones (*metacarpals*) or in-step-bones (*metatarsals*) supporting the large inner digits (3 and 4) of the fore and hind feet respectively are fused into a “cannon bone” (fig. 364). Rigidity is thus secured. The crowns of the grinders are *selenodont*, *i.e.* they possess curved transverse ridges well suited for chewing

grass and other comparatively hard plants, such as grow on plains. Canines are absent except in camels and chevrotains, and, save in the former, all the upper incisors have disappeared, their place being taken by an elastic horny pad.

The well-known power of rumination or "chewing the cud" possessed by members of this group is related to digestive organs of peculiar structure. We find that the stomach (fig. 365) is divided into four successive compartments — (a) the large paunch (*rumen*); (b) the honeycomb stomach (*reticulum*), so called from the character of its lining; (c) the book or manyplies (*psalterium*), the mucous membrane of which possesses numerous leaf-like folds; and (d) the tubular reed (*abomasum*), which receives the gastric juice and communicates with the small intestine.

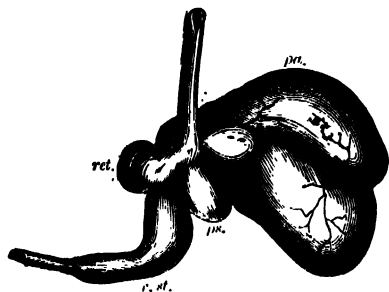
Herbage is first cropped without chewing, passes into the paunch, and thence into the second compartment, where it is made up into boluses. These are returned to the mouth as "cud", thoroughly masticated, and once more swallowed, this time being strained through the manyplies, and ultimately reaching the reed, to be subjected to the action of the gastric juice.

There can be no doubt that this remarkable process was evolved as a protective measure against carnivorous mammals. It enables a large supply of food to be hurriedly swallowed, and afterwards to be dealt with at leisure in a place of safety. Without being absolutely certain, we are justified in assuming that cud-chewing arrangements were evolved *pari passu* with the characters of teeth and limbs that are now associated with it. In later Eocene times

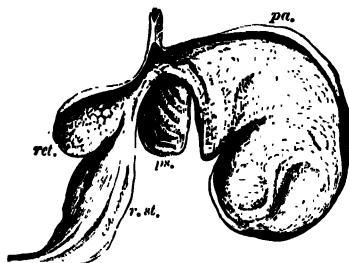


Fig. 364.—Lower portion of the Hind limb of a Horse

t., Tibia; ca., calcaneum (heel bone); a., astragalus. III, IV, Metatarsal bones of digits III and IV. III is the cannon bone, and IV one of the splint bones.



Stomach of Ruminant (external)



Internal Structure of Stomach of Ruminant

Fig. 365

pa., Paunch or rumen; ps., psalterium, liber, omasum, or manyplies; ret., reticulum or honeycomb bag. r.st., Rennet-stomach or abomasum, the true digestive stomach.

we find Ungulates in which these characters were beginning to appear, and such forms were the probable ancestors of existing Ruminants. To

enumerate them would simply mean giving a long list of names, and it will suffice to say they had a wide distribution through Eurasia and North America during Eocene and Miocene times. A brief account of the history of the existing families will answer our purpose.

CAMELS AND LLAMAS (TYLOPODS) appear to have taken origin in North America, the earliest known type (*Poebrotherium*) being somewhat like a small antelope, and of Oligocene age. Both camels and llamas were evolved from forms like this, afterwards migrating respectively into Eurasia and South America.



Fig. 366.—The Kanchil (*Tragulus pygmaeus*)

CHEVROTAINS (TRAGULINES) are hornless, deer-like creatures (fig. 366) of small size, with ruminant characters only partially developed. They are now restricted to swampy regions in West Africa and South-east Asia, but remains of very similar creatures have been found in the French Oligocene (*Prodremotherium*) and the German Pliocene (*Dorcatherium*).

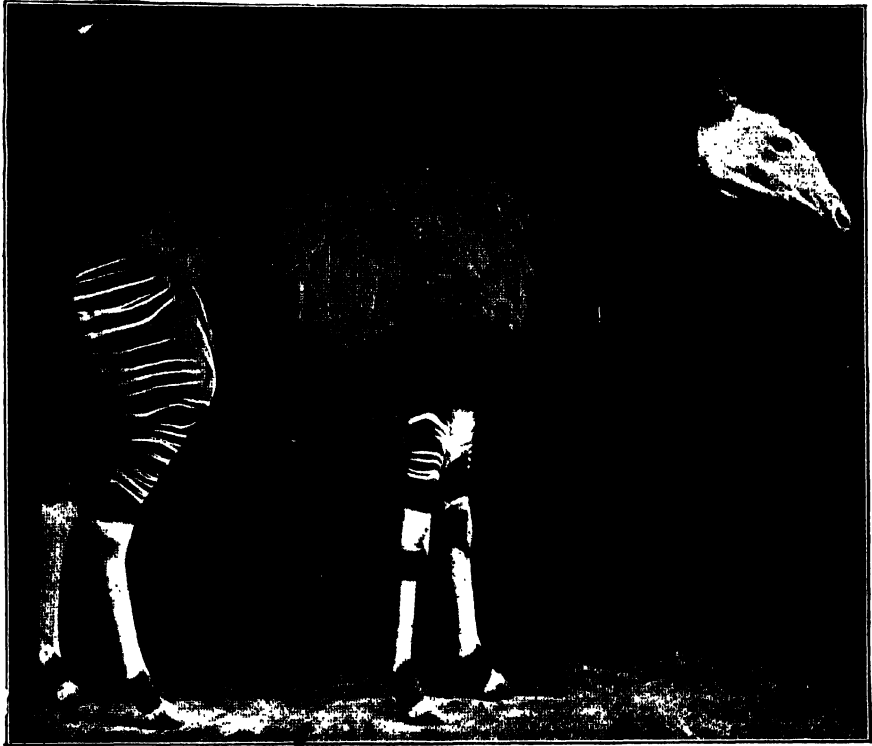
GIRAFFES are essentially Old World ruminants, now only found in Africa. Their elongated limbs, long necks, and prehensile tongues are adaptations to feeding on the leaves and shoots of trees. Far less extreme in its characters,

and nearer the ancestral stock, is the Okapi, native to the equatorial forests of Central Africa (fig. 367).

During older Pliocene times Giraffes ranged from Africa into South Europe and most of Asia. With them were associated Okapis (*Samotherium*, *Helladotherium*, &c.). Older types are so far unknown.

DEER are now very widely distributed, being absent only from the Australian and Ethiopian regions. Bony antlers (fig. 368), used when fighting for mates, and shed annually, are nearly always present in the male, and are also possessed by the female in reindeer. In a typical case, such as that of the Red Deer (*Cervus elaphus*) they become more complex every year.

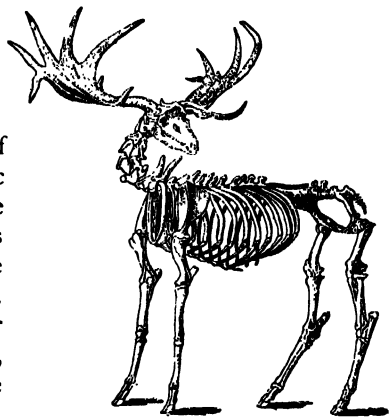
The geological history of the family presents us with a series of stages, in which teeth and antlers became increasingly specialized. In regard to

Fig. 367.—The Okapi (*Okapia johnstoni*)

the latter character, therefore, the Red Deer or similar form repeats the history of the group in its own life-history, another example of the Law of Recapitulation already illustrated in earlier chapters.

The oldest known deer (*Amphitragulus*) has been found in the Oligocene and Lower Miocene rocks of Western Europe. It was entirely hornless and of small size, resembling two existing Asiatic forms, the musk deer (*Moschus*) and Chinese water deer (*Hydropotes*). Antlered species began in the Middle Miocene of Europe and the Upper Miocene of North America.

Of younger types, the Irish deer (*Cervus giganteus*), coeval with prehistoric man, deserves mention on account of its huge antlers, which sometimes attained a breadth of over 9 ft. from one side to the other (fig. 368).

Fig. 368.—Irish Elk *Cervus giganteus*, much reduced

ANTELOPES, SHEEP, AND OXEN are a very dominant Old World group at the present time, and the highest expression of evolution among

Even-toed Ungulates. Both sexes usually possess a pair of horns, which are not shed like the antlers of deer, and consist of a hollow, horny sheath supported upon a bony "core". Such creatures are first represented by small antelope-like animals in the Miocene of Western Europe, and at the end of Pliocene times some of them reached North America.

GNAWING MAMMALS (RODENTS).—This cosmopolitan order includes a great number of simply organized mammals—*e.g.* rabbits, squirrels, rats, and porcupines—mostly of small size, which have not altered very greatly since Eocene times. The small, smooth brain is correlated with a low degree of intelligence, and the success of rodents in the struggle for existence is largely due to their great fecundity, and to the fact that they have become adapted to the most various conditions of life, filling, as it were, all sorts of unconsidered gaps in the economy of nature, some of which could not be occupied by larger creatures. The members of some



Fig. 369.—Skull of Hare. Observe the small upper incisors *i''* behind the large functional ones *i*; *c.p.*, coronoid process; *z.a.*, zygomatic arch.

successful vegetarian orders, *e.g.* Ungulates, have mostly increased in size during the course of evolution (cp. pp. 188, 193), and this has left a place for Rodents among ground animals, while others burrow, climb, or even swim.

Although primitive in most respects, Rodents are highly specialized in regard to their teeth,

which are adapted for gnawing hard substances, such as roots, wood, and bark. They are therefore able to utilize, as food, materials which are rejected by the higher vegetarians, and this has been another factor of success. The canines have disappeared, and the incisors reduced to two large chisel-edged teeth above and below, which grow continuously throughout life (fig. 369). Hares and rabbits, however, possess a *second* pair of upper incisors, which are very small, and placed behind the others. They may be regarded as dwindling structures caught in the act of disappearing.

In the older Eocene of Europe and North America a group of extinct animals (TILLODONTS) has been discovered which represents or comes near the ancestral rodent stock, and enables us to trace the stages in the evolution of a typical gnawing dentition.

Some of the Pleistocene Rodents were of large size, but this direction of evolution has proved unsuccessful, and at present the biggest species is the Capybara of South America (*Hydrochæra capybara*). This is not unlike a small pig, and its dimensions are quite unusual (fig. 370).

FLESH-EATING MAMMALS (CARNIVORA).—We have traced the descent of the Vegetarian Hoofed Mammals from Primitive Ungulates (Condylarthra) living during the Eocene period (cp. p. 185). Side by side with these existed a tribe of PRIMITIVE FLESH-EATERS (CREODONTS) both

in Europe and North America. They include the bear-like *Arctocyon*, a form *Hyenodon* (fig. 371) that faintly resembled a hyæna, and *Patriofelis*,



Fig. 370.—Capybara (*Hydrochirus capybara*)

possibly ancestral to the existing PINNIPEDS, including seals, sea-lions, and walruses. As this last group has already been considered (cp. p. 175) we are here only concerned with terrestrial Carnivores or FISSIPEDS.

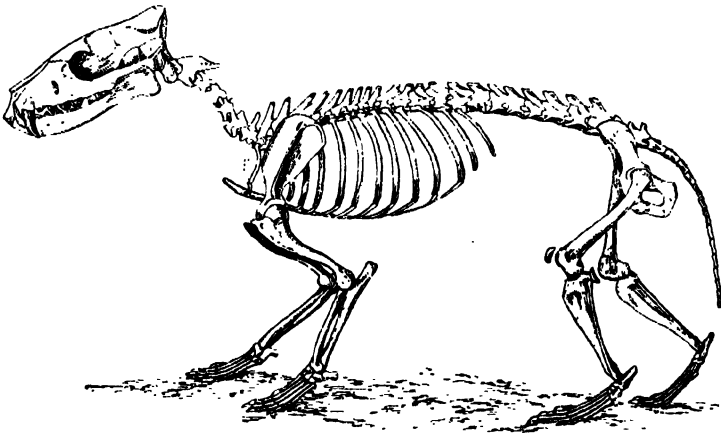


Fig. 371.—Skeleton of *Hyenodon* (After W. B. Scott).

Primitive Flesh-eaters are represented in the older Kainozoic of Patagonia by a group of forms (SPARASSODONTS), presenting marked resemblances to the flesh-eating Marsupials of Australia and Tasmania.

While the Ungulates were gradually evolving on the northern land-masses, in adaptation to a vegetarian life in plains, the Carnivores were acquiring characters fitting them for an aggressive existence in the same area. In other words, hunters and hunted were evolving together, the



Fig. 372. The Asiatic or Indian Civet (*Viverra zibetha*)

structural advances in each influencing those in the other. Primitive Ungulates and Primitive Carnivores sprang from the same vegetarian swamp-dwelling stock, and the early representatives of both are much alike, though the latter already began to exhibit those characters of limbs and teeth that are associated with the carnivorous habit.

The limbs of Ungulates have become structures adapted to rapid

locomotion, and that only: their teeth and other digestive organs have acquired a high degree of specialization in relation to vegetable food. Carnivores have necessarily evolved in such a way as to become destructive machines of high order. Rapid movement is, of course, necessary for them, but is largely supplemented by craft and intelligence; hence the brain has become relatively larger and more complex than in Ungulates. Since the limbs have to be used for seizing, holding, and the like, retention of mobility is essential, and though a tiptoe (digitigrade) attitude has been assumed by many Carnivores, the large reduction of digits and fusion of parts typical for Ungulates could not take place in Carnivores. And claws were evolved instead of hoofs.



Fig. 373.—The Fousa (*Cryptopithecus*) of Madagascar

The teeth of Carnivores have acquired marked peculiarities in relation to food. The incisors are small, but the canines are sharp tusks, suitable for seizing and holding prey. The cheek-teeth have become laterally compressed, with cutting crowns, while each last premolar above and first molar below have developed into much-enlarged "flesh teeth" (carnassials) working against each other like scissor-blades.

We will now briefly consider the pedigrees of the chief carnivorous families, *i.e.* Dogs (Canidæ), Bears (Ursidæ), Badgers (Mustelidæ), Civets (Viverridæ), Hyænas (Hyænidæ), Cats (Felidæ), and the extinct Sabre-toothed Tigers (Machairodontidæ).

DOG FAMILY (CANIDÆ).—This includes dogs, wolves, jackals, and foxes, the most primitive existing members of the order. First known from the Upper Eocene of Europe, they had become abundant by Miocene times both in the Old World and North America. An extinct form (*Cynodictis*) from the Upper Eocene and Oligocene of France connects them with Civets and Badgers, while a complete series of extinct types

(*Cephalogale*, *Simocyon*, *Amphicyon*, *Hemicyon*, *Hyænarctos*) unites them with the Bears:

BEAR FAMILY (URSIDÆ).—From Pleistocene times Bears have

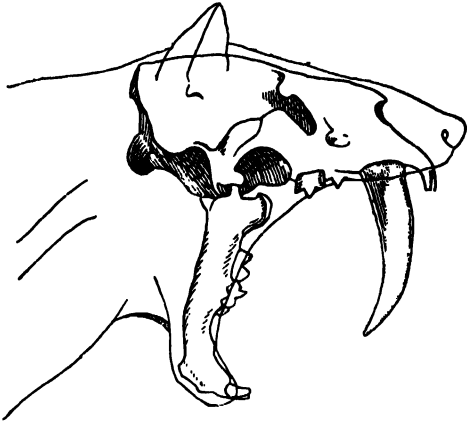


Fig. 374.—Sabre-toothed Tiger (*Machairodus*).
(After W. D. Matthew.)

ranged all over the world, New Zealand and the Australian region excepted. The most interesting extinct species of fairly recent times was the huge European Cave Bear (*Ursus spelæus*), the remains of which abound in the English and Welsh caves. The family was of Eurasian origin. The oldest types were purely carnivorous, but some existing species affect a mixed diet.

BADGER FAMILY (MUSTELIDÆ).—The badgers, weasels, and others here included are common in the Northern Hemisphere.

Their first representatives occur

in the Upper Eocene of Europe, from which continent they migrated into Asia and North America, ultimately reaching South America at the end of the Pliocene period.

CIVET FAMILY (VIVERRIDÆ).—The civets, ichneumons, &c., con-

stituting this group, are comparatively primitive in structure, and purely Old World in distribution. The type genus (*Viverra*) has undergone but little modification since late Eocene times (fig. 372). An extinct genus (*Ictitherium*) from the older Pliocene of Europe and Persia connects this family with the next one.

HYÆNAS (HYÆNIDÆ).

—The members of this essentially Old World family are distinguished by their extremely powerful jaws and teeth, which easily

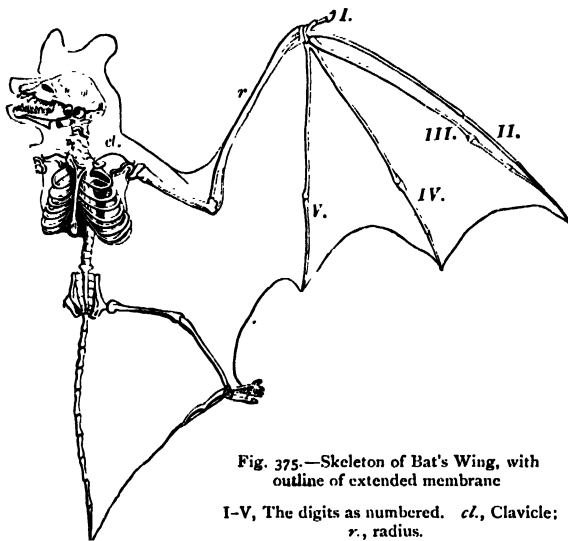


Fig. 375.—Skeleton of Bat's Wing, with
outline of extended membrane

I-V, The digits as numbered. cl., Clavicle;
r., radius.

crush bones. Undoubted hyænas date from the Older Pliocene strata of Greece, Persia, and India, where links between them and *Ictitherium* are also found. The Cave Hyæna (*Hyæna spelæa*) was common in England and Wales during the Pleistocene period.

CAT FAMILY (FELIDÆ).—This group embraces lions, tigers, leopards,

and various smaller forms, representing the highest existing Carnivores. Extinct Miocene types connect them with the civets, as does a remarkable creature (*Cryptorrocta*) still living in Madagascar (fig. 373). The family appears to have originated in Europe during Miocene times, and reached North America at the end of the Pliocene period, subsequently extending its range to South America. The Cave Lion (*Felis spelca*) abounded



Fig. 376.—Ring-tailed Lemur (*Lemur catta*)

in Europe (including Britain) during the Pleistocene, and it was probably a large variety of the ordinary lion (*Felis leo*).

SABRE-TOOTHED TIGER FAMILY (MACHAIRODONTIDÆ).— The members of this group include the most specialized Carnivores. Their name is derived from the huge saw-edged upper tusks, to use which the mouth had to be opened very widely (fig. 374). The ancestral forms of the family have been discovered in the Oligocene of France and North America. The sabre-toothed tiger itself (*Machairodus*) first occurs in the French and German Miocene. During the Pliocene period it spread over Europe (including England), Persia, and India, while in Pleistocene times,

when the largest species lived, it reached both North and South America. Why these creatures should culminate and become entirely extinct in the prehistoric period is difficult to explain. Probably they suffered the penalty of over-specialization.

INSECT-EATING MAMMALS (INSECTIVORA).—These small and primitive creatures, including hedgehogs, shrews, and moles, bear much the same relation to Carnivores that Rodents do to Ungulates (cp. p. 198). They have existed without much change from the Eocene period.

BATS (CHIROPTERA).—The members of this family probably represent an offshoot from Insectivores, but the stages in their evolution are unknown. For the oldest fossil bat (Upper Eocene of France) possessed fully developed organs of flight. The wings (fig. 375) are quite different from those of Birds and Flying Reptiles, being membranes supported by the elongated fingers, but were probably first evolved as parachutes (cp. pp. 160-161).

LEMURS, MONKEYS, AND MEN (PRIMATES).—Human beings excepted, the members of this family are tree-dwellers, with extremities adapted for climbing, and a fairly primitive dentition suited to a vegetarian or mixed diet. Their success in the struggle for existence has been mainly due to a highly developed brain and care of young to an unusual extent.

LEMURS, the lowest members of the group (fig. 376), are small arboreal animals of nocturnal habit, now limited to Madagascar, Africa, and South Asia. In the two latter areas they are but scantily represented here and there. During the Eocene period lemurs were widely distributed through Europe and North America, but became extinct in those continents in the early Miocene, probably owing to competition with the more highly organized monkeys. A Mascarene lemur (*Megaladapis*), that probably became extinct in late historic times, was non-arboreal, possibly aquatic, and as large as a small pony.

MONKEYS are first known from the Middle Miocene. They are distinctly higher than lemurs, especially as regards size and complexity of the brain.

The evolution of **MAN**, and his relation to lower forms, are dealt with in the section on **ANTHROPOLOGY**.

LIST OF WORKS RECOMMENDED FOR FURTHER STUDY

Name.	Author.	Publisher.
FROM THE GREEKS TO } DARWIN }	H. F. Osborn	Macmillan & Co., Ltd.
THE SCIENCE OF LIFE ...	J. A. Thomson ...	Blackie & Son, Ltd.
GESCHICHTE DER ZOOLOGIE	J. V. von Carus ...	R. Oldenbourg.
ORIGIN OF SPECIES ...	Charles Darwin ...	John Murray.
DARWINISM	A. Russel Wallace ...	Macmillan & Co., Ltd.
COLLECTED ESSAYS (Vols. I, } II, VII, and VIII) ... }	T. H. Huxley	Macmillan & Co., Ltd.
BIOLOGICAL LECTURES AND } ADDRESSES }	A. Milnes Marshall ...	David Nutt.
ADVANCEMENT OF SCIENCE	Sir E. Ray Lankester	Macmillan & Co., Ltd.
REPORT, &c., OF THE 1902 } NATURE STUDY EXHIBI- } TION }	J. A. Cockburn and J. } C. Medd (editors) ... }	Blackie & Son, Ltd.
TEXTBOOK OF GENERAL } ZOOLOGY }	H. R. Linville and H. } A. Kelly }	Ginn & Co.
TEXTBOOK OF ZOOLOGY ...	{ T. J. Parker and W. A. } Haswell }	Macmillan & Co., Ltd.
THE NATURAL HISTORY OF } ANIMALS }	J. R. Ainsworth Davis	Gresham Publishing Co.
TEXTBOOK OF COMPARATIVE } ANATOMY }	Arnold Lang	Macmillan & Co., Ltd.
VERTEBRATE PALÆONTOLOGY	A. Smith Woodward ...	Pitt Press.
A MANUAL OF PALÆON- } TOLOGY }	H. Alleyne Nicholson } and R. Lydekker ... }	W. Blackwood & Son.
TEXTBOOK OF PALÆON- } TOLOGY }	C. von Zittel	Macmillan & Co., Ltd.
GUIDES TO THE BRITISH } MUSEUM (NATURAL HIS- } TORY) }	Museum Staff	{ Trustees of British } Museum.

SCIENCE AND THE SEA FISHERIES

BY

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SCIENCE AND THE SEA FISHERIES

CHAPTER

HISTORICAL INTRODUCTION

KIEL COMMISSION.—Although most civilized countries have for several centuries enacted legislative measures for the control of their fisheries, it is only within the last few years that any properly organized attempt has been made to investigate those physical and biological phenomena upon which all intelligent efforts to administer the fisheries must ultimately be based. The credit of establishing the first systematic series of investigations is due to the German Government, which in 1870, on the recommendation of the "Deutscher See-Fischerei Verein", established the "Royal Prussian Commission for the scientific investigation of the German Seas". This Commission, unlike an English Royal Commission, which is generally appointed for a special purpose, and only remains in being until the issue of a report, is a permanent organization, and has been in existence for nearly forty years. The original members were four professors at the Prussian University of Kiel; the present number is five, four being, as before, Kiel professors, the fifth being the director of the German biological station at Heligoland. The Commission has since its establishment undertaken the systematic investigation of the seas adjacent to the German coasts in the interests of the fisheries. Special steamers have been from time to time chartered by the Commission for service at sea. A fishery laboratory was established and maintained at the Zoological Institute of the University of Kiel, and has since been transferred there. Since 1892 a biological station has been erected at Heligoland. The Commission, consisting, as it always has done, of experts and not politicians afflicted with adaphagia, has been responsible for the devising and construction of scientific instruments and experimental fishing gear, and it has also edited the annual reports, the *Wissenschaftliche Meeresfischerei*, perhaps the best series of fishery reports in the world. No other reports that can pretend to compare with them are those of the United States Fish Commission. The German Commission has employed skilled assistants, who have usually at the same time been "Privat-Dozenten" (a position analogous to an honorary lecturer in an English university) in the University of Kiel. Special grants have

occasionally been made by the Government for particular purposes, notably the exploration of the North and Baltic Seas by S.M.S. *Pomerania* in 1871-2; the Plankton Expedition of 1889, when biological surveys of the North Sea and Atlantic were made; the *Valdivia* Expedition of 1890; and more recently the German Antarctic voyage of the *Gauss*. The fisheries have also been investigated from a statistical standpoint, the number of fishermen and fishing boats, the quantity and variety of fish landed in the course of commercial operations at the different ports all being carefully recorded. Daily records were also kept of the physical condition of the sea water. After these statistics had been accumulated for a number of years a comparison of the productivity of an equal area of land and water became possible, and it was found that the sea is from 0.2 to 0.48 times as productive as an equal area of cultivated land. The spawning places of the herring of the Western Baltic were soon discovered at the mouth of the river Schlei, where the eggs were found to be adhering to a fresh-water plant (*Potamogeton*). The actual process of spawning was observed, and the development of the young herring elucidated. From 1877 to 1881 a careful study of the variability of the herring was made by Heincke; it was previously known that the herring has two chief spawning periods, in spring and autumn, and considerable difference of opinion existed as to whether these two groups of herring were two distinct races, and if so, whether these races exhibited any morphological differences capable of measurement. Heincke believed that he was able to answer both these questions in the affirmative; but more recent investigation of the problem shows that his results require further confirmation before they can be finally accepted. A systematic treatise on the fishes of the Baltic was published about this time, and the detailed study of the "Plankton" commenced (see p. 221).

At the outset sea-fishery investigations were supported by Prussia alone, a yearly grant of £750 being made. Each member of the Commission received an annual salary of £45, that of the president being double the amount. The greatest drawback to the work of the Commission was due to the fact that they possessed no vessel of any description, not even a rowing boat. Consequently a considerable portion of their slender funds was absorbed in the chartering of vessels. That so much has been accomplished with such limited means is attributed by Professor Brandt, one of the present members of the Commission, to the fact that they have never been interfered with in their scientific work. It is no exaggeration to say that the work of the Kiel Commission is a model of what fishery investigation should be, and its members (Hensen, Brandt, Reinke, Krummel, and Heincke) have acquired a world-wide reputation for the thoroughness of the researches carried out by them and their assistants. Previous to the founding of the Kiel Commission the scientific investigation of marine phenomena had been due to the efforts of isolated individuals; and though in the majority of cases not undertaken with the special object of acquiring information respecting the development and life-histories of marketable marine fish, nevertheless in several instances valuable facts had been established.

FISH EGGS.—In 1864 Professor G. O. Sars, of Christiania, discovered that the eggs of the cod were small round transparent bodies which floated at or near the surface of the sea, and he successfully traced the development of the young fish both inside the egg and whilst in its larval condition after hatching. It had previously been the general opinion, both among fishermen and others, that the spawn of sea fish, like that of salmon and other fresh-water species, was heavy and sank to the bottom, there to undergo its development. Consequently complaints were numerous as to the destruction caused by the method of fishing known as trawling—a method involving the dragging of a heavy net over the sea bottom—and at various times the British Government was urged to legislate against this method of fishing. The remarkable discovery of Sars of the pelagic nature of the eggs of the cod has since been confirmed and extended to other species of sea fish, and it is now known that nearly all edible sea fish have pelagic or buoyant eggs, the only notable exception being the herring.

The practical importance of Sars' discovery is very considerable, since at least three Fishery Commissions appointed by the British Government were largely concerned with the alleged destruction of spawn and fry of fish by the trawl. The famous Royal Commission of 1863 was the first of these. Numerous complaints as to the destructive action of the beam trawl were made to this Commission, and in particular it was stated that incredible quantities of the spawn and fry of sea fish were destroyed by this method of fishing. It does not appear that the Commissioners (who reported in 1866) were aware of Sars' discovery, although they stated that "the statement that the beam and net of the trawl dragging along the ground tear up and destroy the spawn of fish has not yet been justified by any evidence adduced".

In 1878 the Home Secretary appointed a Commission which was largely concerned with the same problem. Its report was, like that of the preceding Commission, against the allegation of the destruction of spawn by the trawl. In appendices by Frank Buckland are to be found interesting observations as to the spawning habits and eggs of sea fish, in which reference is made to Sars' discovery. The year 1883 saw the appointment of the Trawling Commission, and again a number of unhesitating assertions were made as to the destruction of spawn by the passage of the trawl. By this time the work of Sars was better known; and, moreover, his observations had been confirmed and extended, notably by Professor Spencer Baird of the United States Fish Commission, and also by Professor McIntosh, who was specially appointed by the Commission to make a series of scientific investigations. This piscatorial myth was thus finally disproved, though it is still an article of faith with many non-trawling fishermen.

UNITED STATES FISH COMMISSION.—A year after the establishment of the Kiel Commission the United States Government established their Fish Commission, the original object of which was "to prosecute investigations on the subject (of the diminution of valuable fishes), with the view of ascertaining whether any and what diminution in the number of the food fishes of the coast and the lakes of the United States has taken place,

and if so, to what causes it is due; and also whether any and what protective, prohibitory, or precautionary measures should be adopted in the premises, and to report upon the same to Congress". A commissioner of recognized scientific attainments was appointed, and the work of the United States Fish Commission has been carried on systematically and uninterruptedly since its establishment. Its work has arranged itself into three main groups: exploratory, statistical, and piscicultural.

The exploratory work included a detailed investigation of the marine, lacustrine, and fresh-water fisheries of the United States, and more recently of foreign countries, and incidentally the collection of zoological and botanical specimens for faunistic and museum purposes. The statistical branch is naturally concerned with the collection of commercial fishing statistics, special attention being paid to the destruction caused by various methods of fishing with the view of ascertaining whether overfishing exists. The third branch, that of fish culture, though not originally contemplated by Congress, has developed to a very considerable extent. The propagation and acclimatization of fresh- and salt-water fish is the main object of this third section of the Commission's work. No efforts have been spared by the United States authorities to make their Fish Commission—what it is undoubtedly to-day—the finest in the world. European efforts pale into insignificance when compared with the magnificent equipment provided for the United States savants.

In the report of the United States Commissioner of Fisheries for the fiscal year 1907 a detailed account of the present work of the Bureau (as it is now called) is given. That year was a successful one as regards fish hatching. In the rivers of the Atlantic seaboard shad, salmon, striped bass, white perch, and yellow perch were planted; in the streams of the Pacific coast quinnat salmon, blueback salmon, silver salmon, humpback salmon, and steelheads; the Great Lakes were stocked with white-fish, lake herring, lake trout, and pike perch; the numerous interior lakes, ponds, and streams were enriched with land-locked salmon, rainbow trout, black spotted trout, brook trout, grayling, and other species; and in the waters of the north-east coast the supply of cod, pollack, flat fish, and lobster was increased. Over 2,511,000,000 fish fry and eggs were planted, an amount which has only once been exceeded (in 1902). The eggs and fry are distributed by means of special cars, of which six were at work during 1907; these cars travelled in the aggregate over 83,000 miles. Upwards of $3\frac{1}{2}$ million eggs, largely trout and salmon, were presented to various foreign countries, including France, Japan, and New Zealand. The appropriations for expenses during the fiscal year 1907 amounted to well over £130,000. The detailed reports published by the Bureau contain papers of a very diverse nature, as will be seen from a few of the titles selected from a recent volume: "Gas Disease in Fishes", "Sewage Contamination of Oyster Beds", "The Life-History of the Blue Crab", "The Crab Industry of Maryland", "The Commercial Fisheries of the Hawaiian Islands", &c.

SCOTTISH FISHERY BOARD.—The next important organization in point of seniority is the Fishery Board for Scotland. In its original form

"The Board of British White Herring Fishery" was established in the first decade of the nineteenth century; this body was, however, dissolved by the Fishery Board (Scotland) Act of 1882, and the present Fishery Board took its place; and shortly after this the scientific side of the Board was properly constituted (1886).

Previous to the latter date various investigations had been started by the Board, and some of these yielded results of considerable economic and scientific interest. Researches into the natural history of the herring and sprat, with which the names of Goodsir and Wilson are associated, were carried on from 1843 to 1847. The experimental work of Professor Allman (between 1860 and 1863) into the effects of trawling also yielded results of importance. The demersal nature of herring ova was confirmed, and the period of incubation was established. The spring and autumn spawning seasons on the Scottish coast were also observed. Some minor investigations lead us on to 1882, when Professor Cossar Ewart was appointed a member of the Board, and to his efforts the organization of the scientific side of the Board's work is due. In 1886 the Board received a grant from the Treasury which enabled it to purchase a steamer, the *Garland*, and since that date the scientific work of the Scottish Fishery Board has continued to increase in importance. At first the major portion of the work of the Board was carried out at sea on the *Garland*, though a good deal of the material collected was investigated at laboratories not under the control of the Board. The Board's marine laboratory was erected at Tarbert, on Loch Fyne, but it was subsequently destroyed by fire. In 1893 a laboratory and sea-fish hatchery were erected at Dunbar, and finally the present laboratory and sea-fish hatchery were established at the Bay of Nigg, near Aberdeen. To treat in detail of the scientific work of the Scottish Fishery Board is beyond the scope of the present article. It may, however, be stated that many valuable reports—some of economic and others of more purely scientific interest—have been published since 1886. Investigations into the rate of growth of fishes, the determination of the size and age at which spawning first occurs, the estimation of the number of eggs produced by the adult females of the various species, the migratory movements, the incidence and duration of the spawning period, the distribution of fish with respect to seasons, and the food of the commoner species have all been duly considered. Faunistic investigations of less general interest, the collection of commercial fishing statistics, and the hatching of sea fish are likewise undertaken by the Board.

The annual report of the Board (Part III, Scientific Investigations) for 1906 will give the reader a good idea of the scientific work now being carried on. During the year plaice fry were dealt with at the hatchery, and over 4½ million were successfully hatched out and placed in the sea. Owing to a serious accident, involving loss of life, to the vessel engaged in this work, the number for 1906 was much less than usual. In 1902, for instance, over 55 million fry were hatched and "planted" in the sea. In accordance with an arrangement with certain of the Scottish County Councils, the scientific and technical instruction of fishermen has been

undertaken. A typical report (that for 1905) deals with trawling investigations, with investigations on the herring fisheries of the Firth of Clyde, with the food value of the herring at different stages of its development, with the rate of growth and age of the herring, with the rate of growth and age of food fishes, with the Tay sprat fishery, the specific characters of the cod family, the otoliths of fishes, and other matters.

ENGLISH RESEARCH.—England, unlike Germany, the United States, and Scotland, has no central organization for the prosecution of scientific research on marine problems connected with the sea fisheries, but there are several societies or committees which have done good work in the past in this connection. The Marine Biological Association of Plymouth was founded in 1884, and its laboratory opened in 1888. The declared objects of the founders of this Association were, “to promote researches leading to the improvement of zoological and botanical science, and to an increase of our knowledge as regards the food, life-conditions, and habits of British food fishes and molluscs”. The Marine Biological Association is a body which has done excellent work in the promotion of research in pure science and the special education of university students in methods of marine investigations—both biological and physical; and it has incidentally been of assistance in throwing light upon certain problems connected with the sea fisheries. More recently this Association has been closely connected with the International Council for the exploration of the seas, but this will be referred to later. In 1886 the Association received a grant of £5000 from the Treasury towards the construction of their laboratory, and in addition from 1888 to 1891 an annual grant of £500, raised in the latter year to £1000.

Cunningham in his work on *Marketable British Marine Fishes* says: “Besides the investigations noted in the present chapter, which have contributed largely to our knowledge of food fishes, the Plymouth Laboratory has to reckon, as a no less important outcome of its activity, a long list of scientific memoirs on the embryology and anatomy of marine organisms of all kinds, the result of researches made within its walls by British and foreign naturalists who have availed themselves of the facilities for study there provided”.

On the West Coast the Lancashire and Western Sea Fisheries Joint Committee have established and maintained two laboratories, one at the University of Liverpool (since 1892), and the other at Piel near Barrow in Furness (since 1897). With the latter institution a sea-fish hatchery is connected, where about fourteen million plaice and flounder larvæ are hatched annually and liberated at suitable localities in the vicinity. Seventeen annual reports of the Lancashire Sea Fisheries Laboratory have been issued, that for 1908 being the seventeenth. The Committee possesses a large and powerful steamer, built at Dartmouth in 1907, which is specially equipped for marine investigations.

Since its establishment under the provisions of the Sea Fisheries Regulation Act of 1888, this Committee has realized that sound administration and effective legislation must be preceded by accurate scien-

tific research. In addition to hydrographical and biological investigation undertaken at the expense of the rates (a maximum rate of one-sixteenth of a penny in the £ is allowed under the order establishing the district; of which three sixty-fourths are usually allotted to administration and one sixty-fourth for scientific research), similar to that undertaken by state aid elsewhere, the Committee does other scientific work with its scientific allowance. Classes for fishermen are held during the spring months at their marine laboratory at Piel. *Bona fide* fishermen resident in the administrative county of Lancaster are selected to attend instruction of a fortnight's duration, an honorarium being granted them for their expenses and as compensation for the loss of their fortnight's fishing. The instruction, which is essentially of a practical nature, is mainly intended to bring home to the fishermen the *rationale* of the Committee's by-laws. These classes have recently been officially recognized by the Board of Education. The laboratory is also available for instruction of elementary and secondary teachers in the elements of marine nature study, and these classes are likewise recognized by the authorities at South Kensington. Research students are admitted free, the only charge made being a modest weekly sum for board. The protection and development of the valuable shell-fisheries of the West Coast are also objects of the Committee's solicitude. Under the provisions of the Sea Fish (Shell-fish) Regulation Act of 1894 the stocking and re-stocking of public shell-fish beds has been undertaken, with the result that great benefit has been derived by the poorer class of fishermen. Periodical bacteriological examination of shell-fish beds in the interest of public health are also made, and although the Committee (not being a public health authority) possesses very limited powers of checking pollution, it is hoped that an improvement will shortly be effected in this direction.

On the East Coast of England the Northumberland Sea Fisheries Committee established a marine laboratory at Cullercoats, which was destroyed by fire, and has only recently been replaced by a new building. An annual report on the scientific investigations carried on under the auspices of the Northumbrian Committee is edited by Mr. A. Meek of the University of Durham. The scientific work carried on by the other fishery committees is inappreciable in amount.

• IRISH RESEARCH.—Ireland has only recently commenced to explore her fishing grounds from the scientific standpoint, but much good work has been done during the last few years by the young and vigorous Fisheries Branch of the Department of Agriculture and Technical Instruction under the able superintendence of Mr. E. W. L. Holt. The Department was rendered possible by the provisions of the Agriculture and Technical Instruction (Ireland) Act of 1899, and research is now carried on strenuously both at sea on the fishery steamer *Helga*, and on shore at a laboratory on the coast of Galway; a voluminous report of the scientific investigations being issued annually. It must not, however, be imagined that the scientific study of the Irish coasts had been entirely neglected previous to 1899. Both the Royal Irish Academy and the Royal Dublin Society had instituted surveys of the West and

South coasts with the view of ascertaining the possibility of establishing definite fisheries in those localities. The Rev. Spotswood Green, at present Chief Inspector of Fisheries for Ireland, was the first naturalist engaged in this work. The report of the Royal Dublin Society for 1893 contains a valuable account of fishing and scientific explorations off the West coast.

OTHER COUNTRIES.—In addition to the organizations mentioned above, many of the other North European countries followed the example set by Germany in 1870, and subsidized scientific investigation of the Fisheries either directly, or indirectly by means of grants to learned societies. Our space does not admit of even a bare enumeration of much excellent work accomplished in this manner by Norway, Sweden, Denmark, Holland, and Russia. Up to 1899 all these nationalities were working independently, the natural consequence being a certain amount of overlapping and confusion.

CHAPTER II

THE INTERNATIONAL INVESTIGATIONS

In the year 1899 the Governments of Germany, Denmark, Great Britain, Holland, Norway, and Russia were invited by the Swedish Government to send delegates to a Conference at Stockholm, which was convoked "to elaborate a plan for the joint exploration in the interests of the sea fisheries of the hydrographical and biological conditions of the Arctic Ocean and the North and Baltic Seas". A subsequent Conference was held at Christiania in 1901, and as a result of the reports of the delegates attending these Conferences the British Government was induced to enter into an arrangement with some of the other nationalities of Northern Europe for the exploration of the North and neighbouring seas from a hydrographical and biological standpoint, with the view of solving certain problems connected with the sea fisheries. A permanent International Council was formed, consisting of two representatives of each participating nation, and at the first meeting of the council, held at Copenhagen in 1902, it was decided to establish a central office at Copenhagen and a laboratory at Christiania. In addition, each country agreed to provide a special steamer, with the apparatus necessary for marine research, and to furnish and maintain one or more marine laboratories on land where the observations and collections made on board the steamer might be worked out in detail.

The conduct and management of the British share of the investigations was entrusted to the Fishery Board in Scotland and the Marine Biological Association of Plymouth in England, each of these bodies being granted an annual sum of £5500 for their expenses incurred in and for these investigations. In Scotland the observations at sea were carried out on two vessels, H. M. S. *Jackal*, which was mainly employed in making

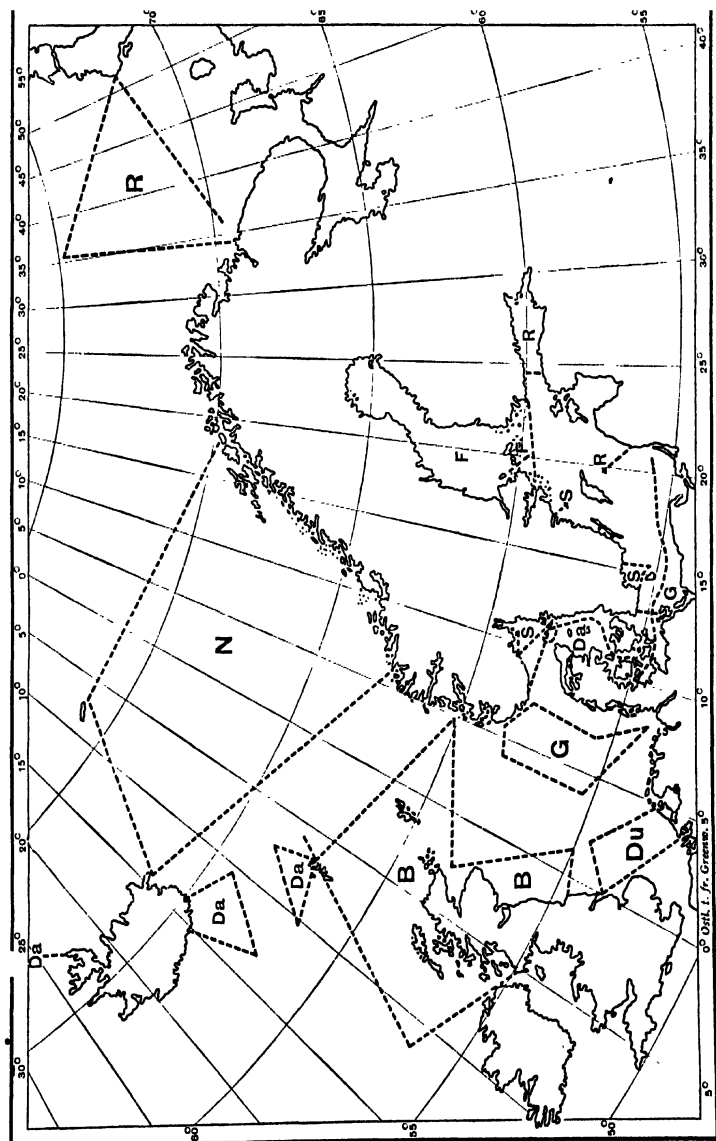


Fig. 377.—Areas assigned to the Nations taking part in the International North Sea Investigation—B, British; Da, Danish; Du, Dutch; F, Finnish; G, German; N, Norwegian; R, Russian; S, Swedish

periodical or seasonal cruises for hydrographical purposes, and the *Gold-seeker*, a steam trawler altered in order to fit her for scientific work. The collections were worked out in detail at Dundee in the laboratory of the University, and at Aberdeen under the able direction of Dr. T. Wemyss Fulton, superintendent of scientific investigations to the Fishery Board, at the Board's laboratory at the Bay of Nigg. In England the work at sea was carried out on a modified steam trawler, the *Huxley*,

and a small steam yacht, the *Oithona*, the property of the Marine Biological Association. The details were worked out at the Association's laboratories at Lowestoft and Plymouth. The areas investigated by the different nationalities may be seen on reference to the chart (fig. 377).

A detailed account of the personnel, regions of investigation, institutions, and steamers is given in the reports of the British delegates attending the meetings of the International Council for the Exploration of the Sea in 1903, 1904, and 1905 (Cd. 3033, pp. 12-21). The original arrangement entered into by Great Britain was to participate in these observations for a period of three years only. This was subsequently extended to five years, then to six, and in March, 1908, the Government decided to continue their grant for the financial year 1908-9; though in the meanwhile a Treasury Committee had been appointed (October, 1907) "to inquire into the scientific and statistical investigations now being carried on in relation to the fishing industry of the United Kingdom, and to report what work of this character is required in the interests of that industry, and by what methods or agencies it can be most usefully and economically carried out in future".

The principal endeavours of the International Council were:—

I. The investigation of hydrographical conditions;

II. The study of the biological conditions of the seas; and

III. "The solution of the problem how far the deep-sea fishery as a commercial industry stands in general on a rational basis; whether the quantities and consumption of fish taken from the seas mentioned (the North and neighbouring seas) are in a proper proportion to the production occurring under the prevailing natural conditions; and whether any disproportion between production and consumption arises from a general or local overfishing or from an injudicious employment of the fishing apparatus at present in use."

One of the first duties of the International Council was to appoint committees of experts to investigate specific problems. One such committee was formed to supervise the hydrographical observations; another undertook to look after the migrations of the most important food fishes of the North Sea, especially the cod and herring; a third investigated the biology of the plaice and other flat fish captured by the trawl with special reference to overfishing; and there was, finally, a committee for the fisheries of the Baltic. Each committee was in charge of a convener, whose duty it was to collate such information and reports as might be from time to time communicated to him by the members of his committee; to draft an annual summary of their results, and after consultation with his colleagues to forward the version authorized by them to the bureau of the International Council. The reports before publication would be submitted to a full meeting of the Council for discussion.

Naturally much of the work of the International Council is incomplete. The investigations are still going on, but the annual reports already published furnish us with much material which can be incorporated into the detailed statement below.

THE HYDROGRAPHICAL WORK.—Of recent years considerable atten-

tion has been devoted to the study of hydrographical methods in fishery research. These methods, which were first brought into prominence by the famous *Challenger* expedition, have now been perfected, or at any rate improved to a very considerable degree, and they have been and are used extensively not only by the International Council but by other societies engaged in marine research. These hydrographical investigations have for their object the determination of the chief physical characters of the sea water in the different regions of the extensive area shown in fig. 377.

The characters which are of importance in tracing the movements of large masses of sea water are the temperature, salinity, density, and the gaseous contents, these latter being chiefly oxygen, nitrogen, carbon dioxide, and sulphuretted hydrogen. The principal instrument used in collecting representative samples of sea water is the Pettersen-Nansen water bottle (fig. 378). The perfection of this instrument is "not the least creditable" of the work of the International Council. The "bottle" affords an almost perfect means of collecting samples of water from the sea bottom or from any required intermediate depths, and at the same time the temperature *in situ* is accurately recorded. It consists of a central chamber in which is fixed a delicate deep-sea thermometer. Round this central chamber are a number of concentric cylinders of ebonite and brass. The bottle is lowered in an open condition, and when the re-

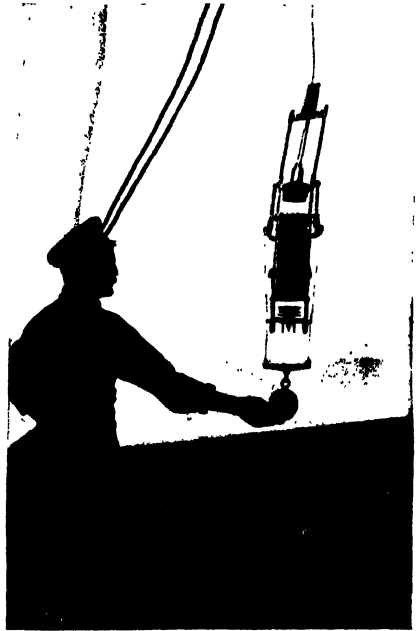


Fig. 378.—Pettersen-Nansen Water Bottle

quired depth is reached it is closed by means of a "messenger", a weight which slides down the line to which the bottle is attached. Both the central and concentric cylinders are then filled with the water present at the depth to which the instrument was lowered; the thermometer registers the temperature of this water in the central chamber, and being surrounded by three or four concentric shells of water, heat is only very slowly conducted in either direction through these walls of water. While the bottle is being hauled through the water the temperature does not appreciably rise. The salinity, that is the weight of solid saline matter per thousand grammes of water, is subsequently determined at one of the shore laboratories. What is actually performed is an estimation of the percentage of the halogens present by precipitating these substances by nitrate of silver. The total solids in solution are then calculated by means of hydrographical tables. By means of these data it becomes

possible to trace the movements of large bodies of salt water and to determine at given seasons whence the water in our seas is derived. The movements of shoals of fish are certainly correlated in some manner with the movements of vast masses of water of a certain temperature and density. The anchovy fisheries of the Scheldt fluctuate with the sea temperature, and the arrival of the autumn herring off the Norwegian coast corresponds with the appearance of water of high temperature and medium salinity.

The international investigations have already shown that the Atlantic current which bends around our Northern coasts into the North Sea is marked by an annual pulsation intensified in the earlier and shrinking in the later months of the year. This periodic phenomenon may at times be obscured or interrupted, as was the case in the autumn of 1895, when the whole of the north-western part of the North Sea was flooded by Atlantic water. Considerable additions have been made to our knowledge of the remarkable mass of cold water which is found at the bottom of a large area of the northern North Sea; this water, unlike that in shallow seas, attains its maximum temperature nearly in mid-winter. Another periodic phenomenon noticed in the North Sea is the annual expansion and contraction of coast water of low salinity. This water, which is confined to a narrow zone in midwinter, spreads rapidly seawards in spring and summer, and doubtless plays an important rôle in the dissemination of the organisms which are found floating in the sea (Plankton).

In the English Channel, owing to the rapid and complex tidal streams which occur in a somewhat limited area, the conditions are more complicated and difficult to investigate. It is claimed that the hydrographical observations during 1903 show that the direction of the flow of the waters of the English Channel was from west to east, and that they were derived from a northerly current of high salinity from the Bay of Biscay and from a southerly current of less salinity from the Irish Sea and Bristol Channel. The meeting place of these waters is stated to be south of the Scilly Islands in mid-channel, and it was generally found that the salinity of the water increased as this point was passed from west to east. Because of the varying salinity and temperature of these two currents, it has been found that at the entrance to the Channel the water is often divided into distinct layers, whilst the changes of their relative velocity, combined with the general up-channel drift, give rise to alternate areas of high and low salinity which follow one another eastward. On the line between the Isle of Wight and Cape Barfleur the salinity was always found to be low—a state of things probably due to the discharge of fresh water from the Seine and the Hampshire Basin. The presence of denser water south of Beachy Head points to the occasional passage of a current of high salinity across this line. The conclusions derived from a study of this area during 1903 are that the Channel waters in the summer and early autumn were derived largely from the Irish Sea, while during the rest of the year the high-salinity water of the Bay of Biscay preponderated.

The determination of surface and bottom currents is accomplished by means of drift bottles. For surface currents short-necked strong bottles are weighted with a small quantity of sand, so that when immersed they float with as little of the neck protruding as possible (to obviate wind effects). Each bottle has enclosed in it a stamped, addressed, and numbered postcard, requesting the finder to forward it with information as to date and place of finding. The bottles are made water-tight by covering the cork with paraffin wax, and are thrown overboard at intervals from the scientific steamer, which makes a special journey along previously selected lines. The velocity of the steamer being known, the points at which the bottles are dropped can be marked on a chart, and when the postcards are returned to the laboratory the journeys performed by the bottles can be traced. It has been found that in a somewhat circumscribed area such as the Irish Sea, from thirty to fifty per cent of these drift bottles are picked up and the postcards returned.

The International Council has recently investigated deep-sea, *i.e.* bottom currents, by means of drift bottles so weighted and balanced as to hang just poised over the sea bottom, drifting with the currents. Five hundred of these bottles were cast out in the northern part of the North Sea during the latter half of 1906, and by January, 1907, ten per cent had been recovered and returned by the captains of trawlers. This experiment is to be repeated on a much larger scale. For the present it must suffice to say that the bottom currents in the region investigated set westward through the Fair Isle Channel, southward along the East Coast of Scotland, and northward in the region midway between our own and the Norwegian coasts.

THE PLANKTON.—The term "Plankton" is applied to those marine organisms which merely drift, and are consequently at the mercy of wind and tide; animals like fish and mammals which are capable of swimming and of making headway against a current are termed "Nekton"; whilst fixed organisms such as sea-lilies (Crinoids) are grouped together as "Benthos". Upon the planktonic plants, as will presently be shown, all marine life ultimately depends, and apart from many features of scientific interest, the determination of the constituents of the plankton and its seasonal variation is a matter of considerable practical importance, since it serves directly as the food supply of some of our most valuable commercial fishes, notably the herring, anchovy, mackerel, pilchard, and sprat. These plankton-feeders possess comb-like structures attached to the gills. These structures, the so-called gill-rakers, act as strainers. During respiration sea water is taken in through the mouth and passed out over the gills, and at the same time the minute organisms present in the water are retained by the gill-rakers whence they are brushed off by the fish's tongue and swallowed.

The nature of the plankton is now fairly accurately known, its organisms have been identified and described, and more modern research has been directed to its quantitative estimation, to its chemical analysis, and the determination of its seasonal variations. Most marine groups of organisms are represented at some stage or other of their life-history

in the plankton. Minute plants, such as diatoms; organisms which are doubtfully vegetable or animal, such as some of the *Peridineæ* and numerous representatives of the crustacea, mollusca, and worms, are all met with. In addition, the free-swimming larvæ of crustacea, such as the crab and lobster; of molluscs, such as mussels, cockles, and oysters, and the eggs and young of our edible fish, are represented at certain seasons of the year. Plankton is collected by means of fine-meshed nets of muslin or silk bolting cloth; these nets are known as tow-nets,

because in their original form they were towed horizontally through the surface layers of water. In recent years attention has been concentrated on the accurate determination of the plankton in a given volume of sea water, and for this purpose many nets have been devised, the most successful being that of Hensen (fig. 379).

This net in the shape of an inverted truncated cone is lowered vertically to a given depth and then raised perpendicularly to the surface, so that it fishes through a cylindrical column of water, the volume of which can of course be calculated, since the area of the mouth of the net is known, as well as the depth to which it was lowered. The correct estimation of the volume of water fished through is not such a simple matter as might appear at first sight. Various difficulties and objections which arose have been dealt with and answered in detail, more particu-

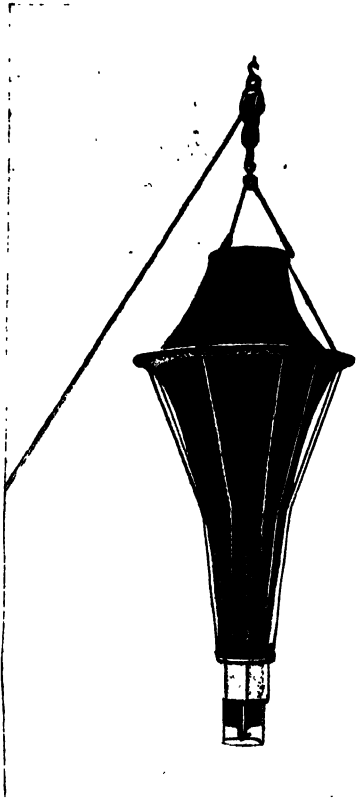


Fig. 379.—Hensen Plankton-net

larly by Hensen and Brandt. Assuming, then, that it is possible to completely fish through a known volume of sea water, it becomes possible to determine the productivity of the sea and to compare it with a similar area of land surface.

As an example of the application of the quantitative plankton method, one may quote the determination of intensity of fishing that was made some years ago in the case of the Eckenförde fishery in the West Baltic. Professor Hensen first of all made a large number of observations with the quantitative plankton net in that area (about 16 square miles) of the Eckenförde waters, where a commercial fishery for cod and plaice is carried on. By means of this net an estimate of the average number of floating

eggs of these two species was made; and it was found that there are in January an average of 30, in February from 45 to 50, in March at least 60, and in April 50 floating eggs of cod and plaice per square metre of surface (with an average depth of 20 metres). These eggs take on the average 15 days to develop under the conditions obtaining in the West Baltic, so that the number above recorded must be doubled in order to give the number occurring per month under a square metre of surface water. This gives from January to April 370 eggs. Now the number of eggs produced by an adult female cod or plaice can be estimated with a considerable degree of accuracy, and the ratio of females to males can also be calculated. From the commercial fishery statistics of the Eckenförde district and the above data Hensen calculated that the number of cod and plaice annually caught by the Eckenförde fishermen would, if allowed to remain in the sea, have produced 23,400 million cod and 73,895 million plaice eggs annually.

These numbers give for every square metre of the 16 square miles fished over 26.6 cod and 84 plaice eggs; a total of 110.6 eggs. This added to the 370 calculated above gives a total of 480.6, which is the number of eggs that would have been produced from all cod and plaice, captured and free, yearly for each square metre of surface water. Consequently 110.6 upon 480.6 gives the fraction of the total quantity of adult cod and plaice actually captured. That is, man destroys each year about one-fourth of the adult cod and plaice in this particular area of the West Baltic.

QUANTITATIVE PLANKTON ESTIMATION.—It has already been stated that the whole of the planktonic constituents of a known volume of sea water can be captured by means of the Hensen vertical net; and therefore a comparison of the variation in the productivity of the sea at various seasons of the year becomes possible. There are four principal methods of quantitative plankton estimation: by volume, by weight, by chemical analysis, and by the enumeration of the individual constituents. The estimation by volume is perhaps the simplest, but is open to several grave objections. The catch having been preserved in alcohol is allowed to settle in a glass measuring cylinder, and then the result is read off after a few days. The main objection to this method is that the nature of the plankton might (and as a matter of fact does) vary considerably although the total volume be unaltered. The estimation by weight and the chemical analysis may be considered together, as the latter method was evolved from the former. Both these methods involve destruction of the plankton, and are therefore objectionable in the case of material obtained by oceanographical research vessels which have been fitted up for a special journey at great expense (*i.e.* *Valdivia*, *Gauss*). Neither method involves special difficulties; ordinary chemical quantitative estimation of carbon, hydrogen, nitrogen, chlorine, the estimation of ash, silica, and occasionally the quantity of chitin, cellulose, or soluble carbohydrates being made. A detailed consideration of the mode of enumeration of the individual organisms is beyond the scope of the present summary.

In brief, the method depends on an adaptation by Hensen of the

process used for the enumeration of the red blood-corpuscles in the human blood. Care is taken firstly, to thoroughly mix the planktonic organisms in a known volume of liquid, and secondly, to take known fractions of this mixture and by means of a special form of microscope to count each separate organism. Elaborate precautions are taken to ensure that the limit of error is reduced to the smallest possible dimensions.

Some of the more interesting results obtained by the enumeration method merit a brief description. There are certain small crustacea invariably met with in the plankton; these are Copepoda (lit. oar-footed), which serve as the main food supply of the herring and other surface-living fishes. Hensen estimated that a litre of West Baltic sea water contained on an average from 72 to 89 Copepoda. The average depth of the West Baltic is 20 metres, and there are present for every square metre of surface water from 80 to 100 billion Copepoda, with a dry weight of 150,000 kilogrammes. In an ingenious manner Hensen endeavoured to measure the appetite of herring for Copepoda, and he finally came to the conclusion that in the 16 square miles of the Eckenförde district there existed food in the shape of Copepoda for 534 million adult herring. The estimation of the free-swimming larvæ of the larger edible crustacea, such as the crab and lobster, is also of practical importance. The larvæ of the edible mollusca, such as the mussel, are frequently present in incredible quantities. On one occasion in the West Baltic it is calculated that 170,000 mussel larvæ were present for each square metre of surface water. If all these developed into adults we should have for each square centimetre of ground no less than 17 mussels, which is obviously a physical impossibility. It follows that only an exceedingly small proportion of the larvæ ever complete their development.

Estimates were made by Hensen of the number of the smaller organisms, such as the microscopic Infusoria, the Peridineæ, and the Diatoms. The number and mass of Diatoms probably exceeds all the other constituents of the plankton taken together. On account of their extreme minuteness the capture and enumeration of these organisms is attended with no little difficulty. Hensen estimated that every drop of water in the Baltic is inhabited by Diatoms. The North Sea and especially the open ocean contain a much smaller quantity of Diatoms than the Baltic. The Copepoda of the North Sea, on the other hand, show no diminution. In the North Sea, in spite of the much smaller quantity of the total catch than in the Baltic, the meshes of the net were much sooner obstructed, and the net itself took on a yellowish-green colour. It therefore seems obvious that there exist in the plankton still smaller organisms which escaped through the meshes, and subsequent research has justified this surmise.

THE CYCLE OF LIFE IN THE SEA.—The animal life in the sea as well as on land is ultimately dependent on vegetable life, which by virtue of its chlorophyll is able to manufacture organic compounds from inorganic substances. This property is dependent on sunlight, and is therefore only possible within depths to which the sun's rays are able to penetrate, that

is, a maximum of 436 yards from the surface. Thus by far the greater bulk of the ocean is unproductive of vegetable life, since it lies to a greater depth than this. It is certain that the diatoms and other floating plants play a far greater rôle in the cycle of matter in the sea than do the attached seaweeds. The animals which inhabit the sea therefore depend ultimately on the planktonic plants.

The amount and composition of the plankton exhibit a large seasonal variation, the autumn and winter plankton being characterized by a predominance of vegetable organisms, so that when compared with the land products it is found that they take a position as regards nutritive value intermediate between rich pasture and lupine. This resemblance is quite remarkable, as will be seen from the following figures:—

		Albumen.		Fat.		Carbohydrates.		Ash.
Rich pasture	...	20.6	.....	4.5	.....	64.6	.....	10.1
Autumn plankton		20.2-21.8	.....	2.1-3.2	.....	60-68.9	.....	8.5-15.7
Lupine	...	20.6	.....	2.6	.....	72.0	.....	4.6

As spring approaches a remarkable change is noticed in the plankton. Diatoms increase suddenly, and we get the percentages of silica very much higher, so that in order to compare with land plants the weight free from ash is taken. The nutritive value of diatoms as compared with pea seeds and lupine is shown by the annexed table:—

				Albumen.		Fat.		Carbohydrates.
Good lupine	...	...	...	29.3	.....	2.8	.....	67.8
Pea seeds	...	...	...	27.2	.....	2.3	.....	70.4
Diatoms	...	...	...	28.7	.....	8.0	.....	63.2

The percentage of fat in diatoms is invariably higher than in land plants, and the albumen is also relatively high.

In the summer animal constituents come into prominence, and it is no longer possible to compare the plankton with the land plants usually used as fodder. The albuminous constituents now predominate.

Fat is in one case low, in another case high, and the carbohydrates are comparatively of small account. With regard to the purely animal constituents of the plankton a comparison has been instituted between the Copepoda and certain edible fish and mollusca. The comparison is not quite exact, because in the case of both the Copepoda and the mollusca the carbohydrates are to a large extent found in the alimentary canal, which is not removed before analysis, as is the case with the fish. In other respects, that is, for albumen and fat, the plankton Copepoda come between oysters and mussels on the one hand and lobsters and crabs on the other.

To sum up. What happens in the sea is this: The planktonic plants, such as diatoms, utilize the inorganic substances present in the sea water and air, these substances being incapable of affording nourishment to animals. This manufacturing process is aided by the bacteria, which prepare the inorganic substances from materials such as sewage. The

diatoms are devoured by small animal organisms like Copepoda, these in turn by fish, and fish in turn by man. Man himself is ultimately destined for bacteria, and so the cycle perpetually runs its course.

NITROGEN AND PLANKTON.—In tracing the metabolic changes which go on in the sea at all times, the German investigators were struck with the rôle played by nitrogen in the cycle of changes (Stoffwechsel). Brandt has calculated that but for the action of denitrifying bacteria the ocean would long since have been poisoned by excess of nitrogen salts in solution derived from the waste of the land. It is estimated that the rivers of the world convey to the sea annually no less than twenty-nine million tons of nitrogen in the form of soluble nitrogenous compounds. These compounds are attacked by denitrifying bacteria, and are reduced first of all to nitrites, then to ammonia, and lastly to free nitrogen.

The identification of these denitrifying bacteria and the investigation of their action on nitrogenous compounds have been successfully undertaken by the Kiel savants. Where these bacteria are most active, *i.e.* in warmer seas, a considerable denitrification takes place, and consequently the destruction of the most important nitrogen-containing inorganic food materials is here seen at its maximum. In colder regions these bacteria are less active, and less destruction goes on. Consequently colder seas are richer in plankton than those of the tropics; the Arctic Ocean, for instance, being much richer than the Sargasso Sea. In shallower seas the influence of the bottom and the proximity of the land is quite appreciable. Apstein divided the lakes of Holstein into two groups, those rich in plankton and those poor in plankton. Brandt investigated the proportions of nitrates in the different lakes by means of the diphenylamine sulphuric acid reaction. The lakes rich in plankton were found to be also rich in nitrogen, and conversely.

DISTRIBUTION AND VARIETIES OF PLANKTON.—The international investigators have devoted considerable attention to the plankton, and they claim to have extended our knowledge of its distribution in the northern seas. To bring our account up to date a brief review of their results is necessary.

It is claimed that the investigations have succeeded in determining the distribution of the various plankton organisms very exactly, so that one can now not only state the distribution of each single species, but also group together the species which have a common distribution, that is, communities of the plankton forms can be described. A distinction is made between the plankton communities, which are restricted to the coastal waters (the neritic groups), and those which frequent the open sea (the oceanic groups). Each of the larger regions produces several plankton communities, according to the period of the year. Thus the Arctic waters in the neighbourhood of the coasts during the spring months contain a very rich vegetable plankton (neritic Tænio- and Siraplankton), whilst the open Polar Sea contains predominantly an oceanic plankton at this time (*Chaetoceras criophilum*), which later in the year is replaced by another plankton community distinguished specially by numerous specimens of *Ceratium arcticum*. The same holds good for the organisms met with in

the Atlantic waters which stream through the Farøe Channel into the Norwegian Sea along the west coast of Norway, or farther south right into the North Sea. Along the coast we also meet with plankton communities which are characteristic for different coasts.

The success has also been attained here of demonstrating a regular series of plankton communities changing with the periods of the year. Invariably the vegetable plankton plays the chief rôle in this connection. As the planktonic forms characteristic for each region and each period of the year are now known, it is possible to a certain extent to state where a species met with has come from, and therefore the plankton serves as an indicator of oceanic currents.

As stated above, one can follow the Atlantic forms along the west coast of Norway, also into the North Sea and the Skager Rack (*e.g. Arachnactis*); the forms are also known which reach to the Skager Rack, Cattegat, and Baltic through the Jutland current from the English Channel and the southern part of the North Sea, as also the other forms which are carried with the Baltic stream through the Belts into the Skager Rack. To the south-east of Iceland a sharp boundary is found between the Atlantic plankton to the west and the Arctic plankton to the east, which accords with the hydrographical boundary. The Atlantic plankton can be followed in the north along the west coast of Iceland, and the Arctic plankton to the south as far as north of the Farøe Islands (East Iceland Polar Stream). The plankton is thus an important aid to hydrography, and the great mass of observations made by the International investigators will no doubt prove extremely interesting when fully worked out. The plankton is found to vary considerably in its distribution. The Arctic waters are especially rich quantitatively in the summer months, and above all, in the neighbourhood of the coasts. This is also the case with the Liim Fjord and the Cattegat, and further in the basin of the Denmark Straits where the Atlantic and Arctic waters cause a rotation. Other regions, *e.g.* over the Farøe Iceland Ridge, where there is no rotation, are particularly poor in plankton. The causes of these differences are at present imperfectly known.

CHAPTER III

THE NATURAL HISTORY OF EDIBLE FISH

Since Sars' epoch-making discoveries of 1864-5 the main features of the spawning and development of the north European marine fishes have been described with some detail. With the notable exception of the herring, the eggs of which are demersal, the eggs of most of our edible sea fish are pelagic, and in the spring months of the year form an important constituent of the plankton. The description of the spawning and development of the cod or plaice would be applicable to most marketable fish, though naturally with modifications in matters of detail. Put as

briefly as possible, the main facts are as follows. In the spring months or even late in winter the adult fish move out into deep water, the depth varying for different species. It is now definitely known that spawning takes place not on banks, as was formerly thought to be the case, but in depressions in the sea floor. Except in the case of certain Elasmobranch fishes, such as dogfish and skate, the fertilization of the eggs of marine fish takes place in the sea water after the ova have been extruded from the parent fish. The genital products, both ova and spermatozoa, are shed promiscuously into the surrounding water. It is, of course, essential to development that each ovum should be impregnated with a spermatozoon. Whether this act is absolutely dependent on fortuitous circumstances, or whether there is some attractive force, is not at present clear. The fertilized egg undergoes its development whilst floating in the upper layers of sea water, and during this period it is quite at the mercy of wind and tide. The egg is small ($\frac{1}{32}$ in. in the solenette to as much as $\frac{3}{8}$ in. in the halibut), but is visible to the naked eye as a minute sphere of jelly-like transparent substance. With a microscope it is possible to make a distinction between the shell and the contents. The former is strong but non-calcareous, the latter divisible into the yolk, which serves as nutriment for the developing embryo, and the germinal disc, which occupies the lower portion of the egg when floating in the natural position. After impregnation, or fertilization as it is more usually termed the germinal disc commences to segment, and at the same time it gradually grows over and ultimately covers the yolk. The rate of development varies with the temperature; the higher the latter the more rapid the development. After a few days the parts of the young fish's body become distinctly marked off, the head, the tail, the precursor of the backbone (notochord), and the muscular segments being among the first recognizable elements.

After a varying period, usually from a fortnight to three weeks, the young fish is hatched, *i.e.* it escapes from the shell into the surrounding water. At this period of its existence it carries a relatively enormous bag attached to its ventral surface. This bag contains the remains of the yolk, upon which the young larva continues to feed for some few days after hatching. When the yolk is ultimately absorbed the larva feeds on the surrounding plankton. It is a curious but indisputable fact that the larvæ of asymmetrical forms, like the plaice or sole, are like young round fish when hatched, the asymmetry being gradually acquired as development proceeds. The early stages of the development of our marine fishes is fairly completely known, but the larval and post-larval stages have until the last year or two presented considerable difficulties, as they were not captured, at any rate to an appreciable extent, in the ordinary tow-nets.

The International investigators have quite recently designed nets for the special purpose of capturing these larval and post-larval forms, which were supposed to inhabit intermediate depths not explorable by the ordinary tow-net.

Among these nets may be mentioned the "Scherbrunnetz" of Ehrenbaum and Strodtmann, and the "young-fish trawl" of Pettersen. The former instrument is really a large tow-net with a square opening (fig. 380).

The essential feature of the apparatus is a large sheering-board attached to the lower edge of the mouth of the net and inclinable at any angle; by this contrivance the net can be towed at any required depth. The young-fish trawl is designed to fish either at the bottom or at any required intermediate depth. In both cases the nets are composed of material of very fine mesh. By means of these nets striking results have already been obtained, and much material has been accumulated which will doubtless require considerable time for detailed examination.

LIFE-HISTORY OF THE EEL.—Mention may, however, be made here of the work of Schmidt on the post-larval stages of the Gadoids (cod, whiting, haddock, coalfish, pollack, &c.); and his discovery of the spawning place of the fresh-water eel. It has long been known that the eel, as

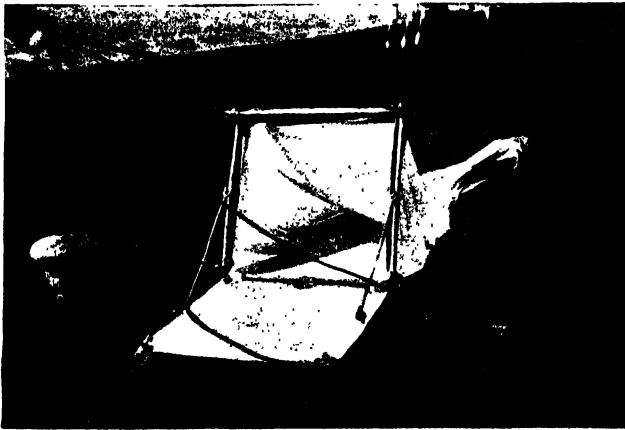


Fig. 380.—Schierbrutnetz

it approaches maturity, descends to the sea, assuming a characteristic coloration as it does so. In the sea it becomes sexually mature, spawns, and there the young are hatched. Young eels are so unlike the adult that when first discovered they were considered to be a distinct species, to which the name "*Leptocephalus*" was given. The situation of the spawning places, the characters of the eggs, the development of the embryo, and other details were quite unknown. Schmidt discovered large numbers of the young transparent forms or "*Leptocephali*" at depths of 1000 metres along the Atlantic slope, and although neither the ova nor the spawning eels have yet been taken, there can be no doubt that the fresh-water eel spawns at considerable distances from the shore and at great depths (fig. 381).

A good deal of the International investigations were naturally directed to the elucidation of the natural history of important food fish. At the commencement, a valuable working hypothesis as an explanation of the migration of fishes was placed at the disposal of naturalists by the Scandinavian investigators, Pettersen, Ekman, and Cleve. According to this theory it is the marine currents arising from the mingling of

the Gulf Stream, the Polar Stream coming from the Arctic Ocean, and the fresh-water effluents of the Continent, which are of prime importance for the explanation of the distribution of migratory fishes. This hypothesis

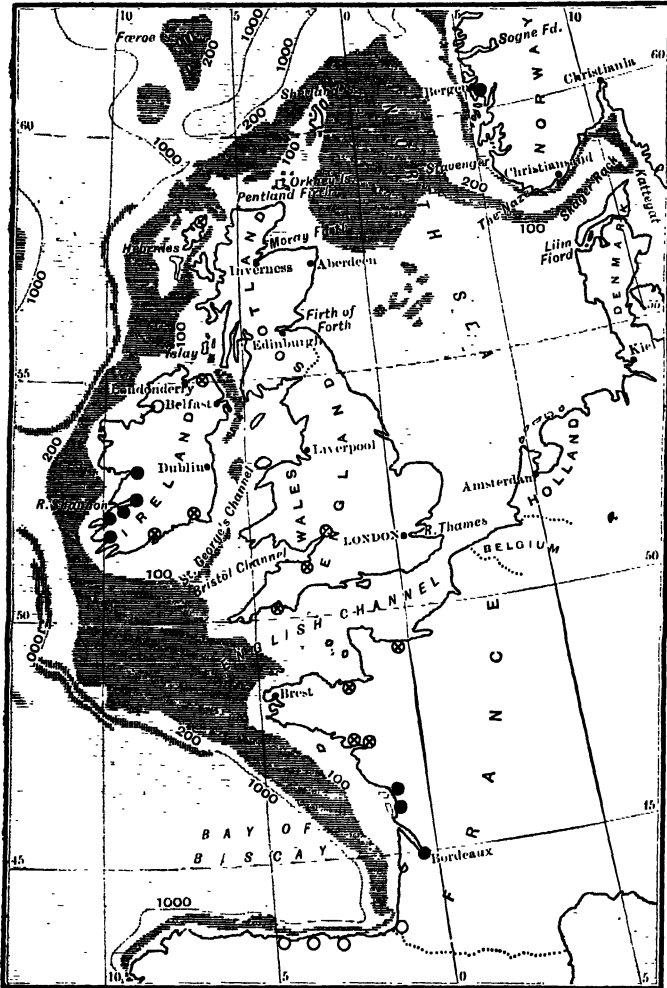


Fig. 38x.—Spawning Grounds of Eel

Localities in which the eel-fry appears—

- in October—December.
- in January.
- ⊕ in February—March.

Localities in which—

- quite young eel-larvæ
 - eel-larvæ undergoing metamorphosis
- } were found.
- 1000 Metre Line.

has been elaborated by these authors in the case of the Bohuslan herring. We are informed, however, "that the International investigations accomplished up to the present do not yet lead to any conclusion on this point, so far as can be judged from the results to hand".

One of the most interesting discoveries with regard to the natural

history of fish made by the International investigators was that of Fulton, who discovered that the cod spawns in autumn in certain parts of the North Sea.

EXPERIMENTS WITH MARKED FISH.—This method of investigation, although employed years ago both by the Scottish Fishery Board and the United States Fish Commission, has only recently been extensively developed. The international investigators, particularly of Sweden, Germany, Denmark, Holland, and England, have marked with labels and then liberated large numbers of flat fish, especially plaice, with the view of elucidating three main problems connected with the life-history and commercial exploitation of this most valuable species. Plaice may be marked in various ways: numbered labels of brass, or aluminium, or brass rings,

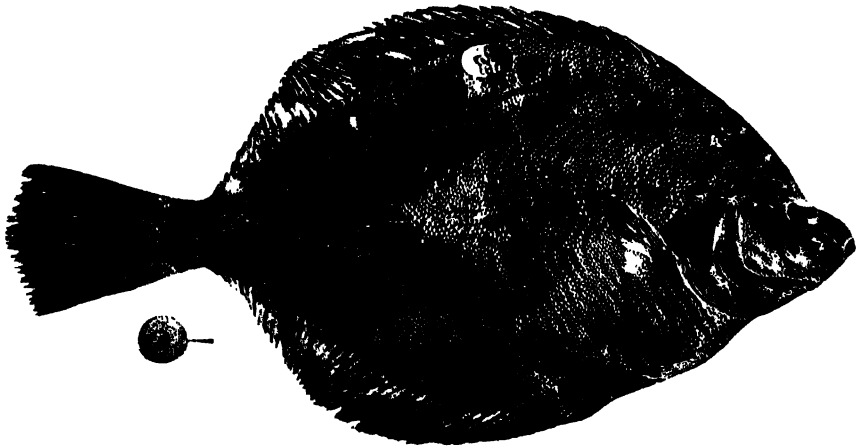


Fig. 382.—Marked Plaice. A separate label is seen to left.

or vulcanite studs being used. Experience seems to show that the numbered label of brass is the most practicable. This label is affixed as follows. A silver wire, about an inch long, has a small loop made at one end, and on to this a bone button is threaded. A hole is now made through the body of the fish, and if this is neatly done the fish loses no blood and exhibits no sign of discomfort. The wire is passed through the aperture and the brass label then slipped on. Finally, the silver wire is bent down by means of a pair of pliers into another loop (fig. 382). Marked fish are kept in a tank supplied with running sea water for several hours in order to see that their vitality is not impaired by the operation, and then they are liberated at carefully selected localities. The co-operation of the fishermen is secured by means of a system of rewards payable for the return of marked fish, with particulars as to date and locality of recapture. Even so it is probable that an appreciable percentage of recaptured fish are not returned to the investigators; in one instance a label was returned which showed unmistakable signs of having recently been in the frying-pan!

Obviously results obtained from experiments of this kind must be

accepted only with extreme caution. It is difficult to estimate whether the marked fish behave after liberation in a similar manner to individuals that have not been tampered with. We have no accurate means at present of ascertaining the proportion of marked to unmarked fishes in any given area, but in the vast extent of fishing grounds included in the North Sea area the proportion must be an extremely small one. There is little justification for making statements as to migration when the paths are traced as the result of the movements of a few individuals. Further, it must not be assumed in the case of fish that have been returned after a considerable time that they have moved directly from the place of liberation to the locality of recapture. In some instances fish have been recaptured after an interval of two years. In such cases the probability is that the fish have wandered about considerably. Results which profess to give an indication of the "intensity of fishing" in a given area are also open to objection. In the same area it is found that the number of recaptured fish varies within extreme limits, according to whether the fish are liberated just before the commencement or at the end of the season's fishing. Although the so-called "intensity of fishing" may at some periods of the year on certain grounds be very high, no deduction as to depletion can be made, since at another period the same ground may be practically unfished.

The rate of growth can probably be determined with greater accuracy. Marking fish does not appear to produce any deleterious effects as regards growth; there is, however, as would naturally be expected, considerable variation in the growth rate of individuals, and before comparisons are made between the rate of growth on various grounds, a much larger number of individuals than hitherto must be dealt with in order to free the result from chance fluctuations. In the case of migratory movements it is claimed that seasonal migration takes place; very possibly seasonal variations in the environment affect the movements of flat and other fish, but there does not appear to be sufficient evidence to enable one to say whether such movements be periodical or not.

It is claimed by the English branch of the International investigations that south of latitude $53^{\circ} 30'$ in the North Sea plaice for the most part travel south during the winter and to the north during the summer. On the other hand, the tendency on the western side of the North Sea north of latitude 53 degrees is distinctly northward in the winter time. It may, however, be stated that there does not appear to be any marked agreement in the results as yet published, and opinion amongst the various investigators is by no means unanimous.

The deduction of the rate of growth is possibly open to less objection than either attempts to trace migration paths or conclusions as to intensity of fishing. Johnstone finds that Irish Sea plaice scarcely grow at all during the first three months of the year, and this (fig. 383) is also the case during the last three months. In April the season's growth begins, and this is most rapid during the months June, July, and August.

The International investigators say that the growth of plaice is much more rapid on some grounds—*e.g.* the Dogger Bank—than on others—

e.g. the Horn Reef; and it is claimed that fish transplanted from the latter grounds to the former grow much more rapidly than in their natural habitat. In fact, the suggestion has been made that it would pay commercially to transplant plaice from one ground to the other. Danish fishermen have for years past transplanted small plaice from the outer waters of the Liim Fjord to the Thisted Bredning, but as the latter ground is practically a salt-water lake the conditions of the experiment hardly bear comparison to a proposal to transplant to the Dogger Bank.

The results up to the present obtained with respect to the intensity of fishing vary extremely, and it would perhaps be as well to refrain from accepting the statements until the experiments have been repeated on a much larger scale. On the fishing grounds of the North Sea,

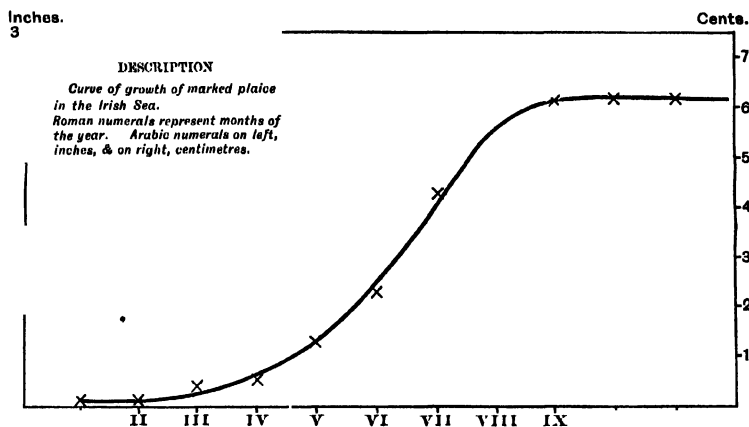


Fig. 383.—Curve of Growth

Skager Rack, and Cattegat the percentages of recaptured fish vary from 4 to 56.

HATCHERIES FOR SEA FISH.—A certain section of scientific experts, being of the opinion that an impoverishment of the fishing grounds was in progress, advocated the establishment of institutions for the hatching of sea fish. Unlike fresh-water species, sea fish can at present only be hatched and not reared; that is to say, they are set free in the helpless condition, and quite possibly weakened by their development under artificial and unnatural surroundings. Hatcheries have not yet come up to a certain point been useful; they have certainly enabled us to study the development of fish in a far more detailed and comfortable manner than would have otherwise been possible. The growth of sea-fish hatcheries has been the less subject to criticism, since they do not in any way interfere with vested interests. As an alternative to restrictive legislation they have been rather encouraged than otherwise by the fishing trade, more especially since their cost has been relatively so little, as of itself to afford but slender grounds for adverse criticism. It is extremely doubtful whether they can in any sense be considered as economic successes.

It was in the United States that sea-fish hatching on a large scale was first practised, and they are still easily first in this field. In 1907 the United States Fish Commission claims to have liberated over 2,511 million fish fry (including both salt- and fresh-water species). Cod, flounders, and lobsters are the chief marine forms dealt with. Canada, Newfoundland, and Norway have also taken up fish hatching. In Great Britain marine hatcheries are established at Aberdeen, Piel (near Barrow-in-Furness) (fig. 384), and at Port Erin in the Isle of Man. The *modus operandi* varies slightly at different institutions, but generally speaking is somewhat as follows. The mature fish are captured in the autumn by a steamer

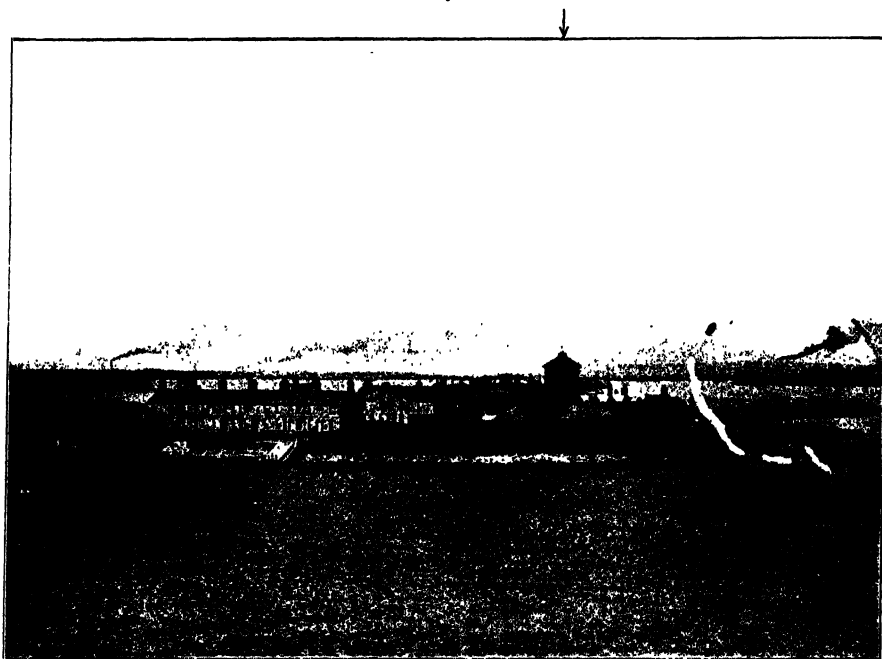


Fig. 384.—Piel Sea-fish Hatchery. Position indicated by arrow.

specially detailed for this work, they are then kept in tanks or ponds through the winter until the hatching operations commence in the following spring. These mature fish are claimed to constitute a reserve of spawners. The eggs, after being artificially fertilized, are placed in wooden boxes kept in constant motion by an automatic arrangement. A constant current of sea water is maintained through the boxes. Shortly after the young fish are hatched, the period of incubation varying from two to three weeks, they are liberated on the off-shore grounds, where similar larvæ are met with in the natural condition.

It would serve no useful purpose to enter into a detailed and destructive criticism of sea-fish hatching in the present article; the reader is referred to the last chapter of Johnstone's work on *British Fisheries* for a moderate and well-stated criticism of marine pisciculture.

CONCLUSION.—One of the most debatable questions connected with

our sea fisheries is that of overfishing, and closely connected with this is the further question of the destruction of immature fish. Both subjects have been investigated and discussed *ad nauseam*; many Royal Commissions and Departmental Committees having sat and inquired into them. Frantic and even tearful exhibitions of piscatorial rhetoric have been displayed at various Fishery Conferences during the last decade, and Government after Government has been accused of deplorable apathy. The fact is, however, that the depletion of the fishing grounds revealed to the Select Committees of 1893 and 1900 has exercised little or no influence on the fish supply of this country. With the advent of large and powerful steamers able to keep the sea in all weathers, the exploitation of more remote fishing grounds has been rendered both possible and profitable. British fishing vessels visit Iceland, the White Sea, the Spanish coast, and even distant Morocco. The discovery of these virgin grounds has resulted in an enormous stimulus to the trawling industry, and the questions of impoverishment of the grounds or destruction of undersized fish have been lost sight of in the scramble for wealth. There can be no reasonable doubt that the home and adjacent fishing grounds are capable of being, and in the past have actually been, fished on to such an extent that the grounds become exhausted, *i.e.* incapable of supporting commercial fishing for a period. Whether such is likely to be the case with the far-distant grounds now being exploited it is very difficult to say. Modern trawlers are fitted up with ice, cold-storage apparatus, or refrigerators. Voyages of a protracted duration are made, and who will be bold enough to place a limit on them? Statistical evidence of the nature now being collected by the Board of Agriculture and Fisheries will alone show, after a few more years' material has accumulated, to what extent the sea fisheries will stand the strain of man's ceaseless and ever-increasing destruction.

LIST OF WORKS RECOMMENDED FOR FURTHER STUDY

Name.	Author.	Publisher.
BRITISH FISHERIES: Their administration and their problems. A short account of the Origin and Growth of British Sea- Fishery Authorities and Regulations ...	J. Johnstone ...	Williams & Norgate, 1905.
THE LIFE-HISTORIES OF THE BRITISH MARINE FOOD-FISHES	M'Intosh and Masterman	C. J. Clay & Sons, 1897.
THE NATURAL HISTORY OF THE MARKET- ABLE MARINE FISHES OF THE BRITISH ISLANDS	Cunningham ...	Macmillan & Co., 1896.

Reports of the Fisheries Inspectors for England and Wales; the Fishery Board for Scotland (especially Part III, which summarizes the scientific work of Britain and other countries); the Irish Fishery Board; the Marine Biological Association; the Lancashire and Western Sea Fisheries Committee; the Northumberland Sea Fisheries Committee; and the publications of the U.S.A. Fishery Department.

